**Algorithms & Power Systems Architecture:**

**Using Historical Analysis to Envision a Sustainable Future**

**Oral History Project**

Interviewee: Ross Baldick

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Transcriber: Temi

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***Abstract*:**

Ross Baldick, Ph. D., discusses his academic and professional background related to electric power systems. His undergraduate education in Australia, and his graduate work at Berkeley and post-doc work at Lawrence Berkeley Laboratory led him to Worcester Polytechnic, and then to the University of Texas at Austin for most of his career. He briefly discusses moving from his experiences working for a utility to his academic research and consulting activities, noting the value of being able to "speak the language" of the utility world when addressing technical matters. He then discusses the influence of *Spot Pricing of Electricity,* by Fred Schweppe, et al., in shifting his focus to markets. He notes that while the book addresses designing power industry markets, it falls short of articulating what it means overall for the

industry to have competition. He notes that working with economists and studying orthodox microeconomics, while at Lawrence Berkeley Laboratory, influenced his understanding of how to address competition's effect on power system operations – in particular explicitly identifying and handling the physics of power grids. He talks about the shortcomings of offer-based electricity markets. His discussions turn to zonal versus nodal markets, transmission constraints, and the potential to apply nodal pricing design to the retail segment of the power system. He discusses his work as a consultant to analyze the ERCOT zonal market and his ability to explain complex technical and economic matters to lawmakers and regulatory commissioners in the process of switching to a nodal market. He identifies this as a significant contribution to improving market policy in Texas and an outstanding contribution of his professional career. He projects the need for greater flexibility in market design to address renewables and to incorporate storage battery and the state of battery charge into models for system operations. He reflects on his forecasts of how quickly these types of changes will be adopted. He recounts an anecdote regarding the relationship between computing capability and modeling and forecasting capability, noting that the market clearing algorithms used today could not have been implemented in decades before the 1990s. He reflects on the value of specialization in today's power industry, especially in his most recent work. He comments on his own commitment to the public interest throughout his career. He underscores that some power system issues are so technically complex that he cannot offer easily understandable explanations for non-experts, but that he works on developing a rapport with audiences so that they will be comfortable when he asks them to trust him on more high-tech topics. He closes by emphasizing the value of learning to communicate technical information to nontechnical audiences for engineers in all types of jobs, but especially for those hoping to influence public policy.

Note regarding Transcript and Timestamps:

Timestamps appear in the transcript but may not align with the recording. Pauses and interruptions may have been removed, and the overall length of the recording may be reduced.

***Transcript:***

Julie Cohn (00:00:02):

This is Julie Cohn, based in Houston, Texas. I'm conducting an online interview with Ross Baldick, who is in Australia and today, in Texas, it is Thursday, November 21st, 2024. Daniel Molzahn will assist with the interview, and Sairaj Dhople will also participate and may ask questions. Dr. Baldick, during today's interview, we are especially interested in your early work on electricity markets as well as computational methods for distributed optimization, power grid vulnerability assessments, and other applications. But first, we'd like to know a little bit more about your background, your educational background, and the professional roles you've held.

Ross Baldick (00:00:58):

Sure. I grew up in Australia and I did my undergraduate degrees at the University of Sydney in Australia. During that time, I was a—what was called an intern—but I think in the US parlance would be maybe technical trainee or something like that, where I worked summers for the then state-owned generation and transmission company in the state of New South Wales. It was called the Electricity Commission of New South Wales. The word commission doesn't mean it was a regulatory commission, which would be the typical meaning in a US context. It means that it was, I suppose, commissioned by the state to set up generation and transmission. So, it was a state-owned generation-transmission company. There were also distribution companies at the time who bundled retail sales. Then in 1986, after having graduated in early 1985, after working for the Electricity Commission of New South Wales for about a year and a half, paying back the kind internship that they had provided me, I took leave without pay to embark on a PhD in the United States at the University of California Berkeley, where I worked with Felix Wu as my advisor.

Ross Baldick (00:02:38):

And on the committee were Pravin Varaiya, Shmuel Oren, and a couple other people, but they're the ones most probably notable in the electricity context. Then I graduated in 1990, and I had an offer to come back to—a standing offer, I guess, to come back to my company. I had an offer from my alma mater, my undergraduate alma mater. But none of, neither of them were terribly attractive to me at the time. And I took on a postdoc at the Lawrence Berkeley Laboratory, which meant that I stayed in Berkeley, which was kind of good from a personal perspective. I'm not sure it was the most adventurous professional jump, but it was good for me at the time. And then in 1992, I started a position at Worcester Polytechnic, which is in Worcester, Massachusetts, in central Massachusetts.

Ross Baldick (00:03:45):

And then about a year and a half after that, there was an opportunity to move to the University of Texas at Austin. At that time Worcester Polytechnic—which is a great teaching school—at the time for me I had concluded that I wanted to be at a research institution. The opportunity for a stronger research institution—Worcester Polytechnic is strong in certain aspects of research—but the opportunity to go to the University of Texas at Austin was a pretty compelling one. So, my significant other at the time, and I moved to Texas and that in fact suited us both from several perspectives. She was interested in English as a Second Language and started a master's degree at UT in ESL and has since become an English as a Second Language professional.

Ross Baldick (00:04:46):

The University of Texas at Austin was, at least from my perspective, a better match to my research inclinations. And I've spent all of my academic career at—all of the rest of my academic career, I should say—at the University of Texas at Austin. I've also done some consulting at various times for parties, typically in Texas. A good deal of that is litigation support, which is not really research, a small amount of it was research-y oriented. And somewhat, perhaps to my concern about my professional contribution, I think some of the most important contributions that I've made was in helping to provide information that contributed to—I'm not sure it was pivotal—but contributed to the adoption of a nodal market in Texas.

Ross Baldick (00:05:47):

As we go through my research, we're going to come to the conclusion that perhaps not much of it has really got out there into products, but I think in terms of policy influence, my involvement in the early 2000s in the debate about moving from a zonal to a nodal market was probably the most significant contribution. Again, we might or might not think of that as highly research-y. It did actually involve some research. But maybe a little different to the algorithmic research that, Julie, you highlighted in some of the questions that you sent online. So, just a warning that maybe some of the algorithmic stuff might be a little disappointing from the perspective of actual implementation. But I at least have a story, I think, for some policy influence, at least in the early 2000s. So, there's the background. Do you have any clarification questions or how should we proceed from there?

Julie Cohn (00:06:58):

I'd just like to ask you a little more about moving from the utility world to the academic world, if there were ways in which you retained some connection back to the utility world.

Ross Baldick (00:07:13):

Well, I think there's two ways. I mean, there's some personal connections that I have, certainly, that I certainly maintain. To be perfectly honest, now that I'm in my sixties, the people that I knew when I was a 20-year-old working for the electricity commission—first of all, it no longer exists as a company. I do have some relationships of people of my age that I made then, including someone that works for the transmission company successor of the electricity commission. Most of the people who were, say, my mentors, we might say, or my seniors at the time, are well and truly retired. And I, and to be honest, I haven't really kept up, kept touch with them. But they were personal relationships. So that would be number one. But number two, there was a lot of practical stuff that I think I could bring to bear from that experience.

Ross Baldick (00:08:15):

I'm not sure I can describe it terribly explicitly. But there were issues about things that somehow are obvious to me, through having had that experience. And I think it's things that one absorbs by osmosis, so to speak, right? To be somewhat metaphorical. I, and I'm not, I'm not sure I can put my finger on it, but there are things that, that in a conversation, where, say, a conversation—and I'm thinking specifically of a relatively recent conversation with some folks from utilities in the Midcontinent ISO footprint—where just the mode of discussion—and it's strange—. I mean, these are—30 years later—utility guys in the US versus experiences with utility people in Australia, where just the mode of conversation, I think, was easier because I had some of that background.

Ross Baldick (00:09:21):

And again, I'm not sure I can put a really strong finger on it, but it, because it's sort of absorbed, right? It's not necessarily like a specific topic in a textbook that one can describe in one sentence. I remember once, for example, I happened to chat with someone and in passing—we were talking about transformers—and in passing, I mentioned a buchholz relay or something like that. It was something that, frankly, you don't really study in any class. It's just something you might see if you were working in a utility. And there are little things that are specific connections to utility experience that made this, as I said, made conversations decades later easier or more comfortable, or maybe it's as simple as that they felt more rapport or more likely to believe whatever line I was spinning them on the basis of having some factoids in my memory.

Julie Cohn (00:10:34):

That's, that's very interesting. I wonder if there were, if any of that osmosis found its way into either the algorithmic work you did, or the arguments that were made about zonal versus nodal.

Ross Baldick (00:10:50):

I'm not sure. I mean, what I would observe is that some of the work in my PhD, which was on loss minimization in distribution systems, looking back, I think of that as not very practically oriented. And I think part of the reason for that, I mean, I can't blame anyone but myself for choosing a research topic. But part of the reason of that, I think, was that my background had been in generation-transmission. And then trying something in distribution without much background, I think I lacked the context to really understand what would be sensible or practical. So, you may be right, but I'm not sure I can put a finger on that. But I certainly can say, you know, I did some work in my PhD that I think probably might have been irrelevant, technical virtuosity, we might say.

Ross Baldick (00:11:54):

And I think that was because it wasn't terribly well grounded in any practical experience in my earlier professional background. So, I've got the case for research not being well informed. Fingers crossed; maybe more market-related work was better informed. But I would also observe that the move to markets was really quite a sea-change. And so, some of the traditional thought that I might have come across from my utility experience—certain of it, I think, we could say was helpful. But other of it, I think is antithetical to the sort of, well, sea-change, paradigm shift—that's an overused phrase—that occurred with electricity markets. I mean, the first book that came out on electricity markets, it's the classic by Schweppe, Caramanis, Bohn, and Tabors.

Ross Baldick (00:13:05):

I've got the authors in the wrong order there. But my reading of that, and I read that in graduate school, studied at graduate school, was that it didn't really come to grips with what it meant to have a competition in a market. So even though that was really a watershed book, absolutely watershed book—I go back to bits of it occasionally now—both in its algorithmic stuff, in the approximations to make things tractable, given the software at the time, and in it, most particularly, its philosophy of trying to get more efficiency into the generation. I think they did not anticipate, at least not in the book, I think, some of the authors now certainly are full on into markets, perhaps they were at the time, but just didn't articulate it in the book.

Ross Baldick (00:14:09):

But the book doesn't really articulate what it means to have competition. What it means to be at risk with an investment. It still envisaged a world where there was some guaranteed rate of return. And I think competition made a real—again, I'll use the word "paradigm shift," from a world where there was rates of return that were guaranteed in some regulatory process to hiving off the parts of the industry that were susceptible to competition or that were newly realized to be susceptible to competition. And allowing competition and allowing companies to go bankrupt, which is really not, for the most part, something that regulated utilities contemplated. And, I would say, not really contemplated in the context of that classic book. So, to sort of tie that together, I think there were experiences from traditional utilities that informed that perception.

Ross Baldick (00:15:17):

But bringing a market in was really a big change in that story. So, I think there were things certainly from my background, that had, if not accepted, the notion of a state-owned or a state-regulated entity. But the zeitgeist of the '90s, or the '80s and the '90s, was to move away from state control and to realize—and state regulation. And to realize ultimately that the electricity—parts of—the electricity industry was susceptible to competition, I think was a pretty big break for a lot of people in the industry. There's a phrase that I read in all sorts of papers, this phrase and paraphrasing of it, and like the paper would start: In the competitive environment that the utility industry finds itself—. And it was like the utility industry was wandering around in a forest, and suddenly the forest opened to a clearing that was a competition, right?

Ross Baldick (00:16:26):

It was sort of: No agency. You know, we used to be controlled by the state or by regulatory—and that's where we've always been comfortable. But now we find ourselves in a different world, right? It is an amazing phrase. Always felt an amazing phrase to me, because it indicated the feeling of absolute lack of agency in this restructured world, where in fact everything was agency. The competitive generating companies had to be their own agents and were responsible for their own profit, and responsible for their own loss, and responsible for themselves not going into bankruptcy, or at least that's how it, perhaps, is ideally supposed to work. In practice, we've hedged a bit at the corners of that quite significantly. And of course, there are parts of the electricity industry that probably are not, despite lots of theoretical effort to make it so, but are not susceptible to much competition. And transmission and distribution are the obvious examples. But system operation is probably another example where you just can't imagine—it doesn't make sense to have two overlapping system operators, or two overlapping transmission owners, or two, for the most part, overlapping distribution companies.

Julie Cohn (00:17:54):

I think we should continue conversing about markets since that's front and center in the conversation so far—

Ross Baldick (00:18:01):

Sure.

Julie Cohn (00:18:02):

Backtrack to talk about algorithms again. So, you described your switch into looking at markets as somewhat dramatic—

Ross Baldick (00:18:15):

It was the second half of my PhD, so it was quite a turnabout in my PhD. And even though I understood—I had imbibed Schweppe's book. I started to then understand—learn about, I should say—and hopefully understand the implications of markets. And those things, I'd say, took me quite a long time to get under my belt. Very important in that context was my postdoctoral experiences, my postdoctoral fellowship experience, both because the timing of that was at the time that these markets were being formed, but also because I then started to understand and put in those pieces. Not, well: We're going to try and run this quotes market, but without really competitive players. To really understanding that the competitive bit is pretty central to that whole world.

Ross Baldick (00:19:30):

And I credit my postdoctoral advisor, Ed Kahn in—he's long since retired—but in helping me with that. He was a team leader at a utility policy group, that may not be quite the right word, at the Lawrence Berkeley Laboratory. But inter alia, I also met people like Steven Stoft—you might consider interviewing him. He's an economist by training and got into electricity. And I started talking and imbibing with economists. And I think that really was an important aspect to imbibe, because without it, you don't understand the implications of why you would want to do all this market stuff. And broadly speaking, it's because of the incentives provided by those competitive forces. And certainly, I had not studied economics formally prior to that.

Ross Baldick (00:20:43):

And so, I then started to read about that. I can't say I am educated formally in economics even now, but I think I understand a little bit more clearly all of those implications and how they fit with the technical necessities of running an electricity market. The technical necessities occur whether or not you have a market, but if you have a market, you need to pay a heed to those technical necessities. Whereas if you don't have a market and you just have everything done in-house, it kind of happens in the course of the utility company, let's say, managing those technical necessities. But when you set up a market, you really hive that off and need to think about it much more explicitly than perhaps it was thought of prior to restructuring. So that resulted in the necessity to discuss a lot of things explicitly, whether or not they were priced explicitly, that had been handled, we might say, implicitly, as part of business as usual by utilities.

Ross Baldick (00:21:57):

So slowly, slowly I learned enough about economics to understand those implications, and then how it reflected back into the electricity industry. Again, I have to emphasize, I'm not a professional economist by training. Giant textbooks like Mas-Colell still—giant economics, graduate textbooks like Mas-Colell scare me a bit. I'm much more comfortable with the more gentle approach by Hal Varian, even though professional economists might find that a little bit too low brow for their highfalutin ways. But I certainly credit Varian's book, *Intermediate Microeconomics*, with helping me to understand and how to marry competition through markets with the technical issues in the electricity industry. Sorry if I've said that a couple of times.

Julie Cohn (00:23:06):

One more question related to your background, and then I'll see if Dan or Sairaj wants to jump in. So, you said that the, your dissertation was about loss minimization in distribution systems. Is there any sort of through line from there to picking up the first book that you chose to read about economics? Or was it just other topics that you were exposed?

Ross Baldick (00:23:33):

I think many PhDs in engineering end up being you know, stapling some papers together. And I made a feeble attempt in the introduction of my dissertation to try to connect the two parts. But the first part was on loss minimization, I think, not incredibly world shattering. And then in 1988 when Schweppe's book came out I together with another student, agreed to read half each of it and present it in a couple of seminars to the seminar group. And it certainly whet my appetite, and that then encouraged me to move much more explicitly into that area. Still not quite understand—certainly at that stage, not just "not quite," but not understanding much about economics. So, it was—you know, a book came out that was very influential, got me interested, got me thinking. I had a few false directions, false paths trying to understand or mimic some of the material in that book.

Ross Baldick (00:24:46):

And then slowly I started to pay attention to orthodox microeconomics. And then understand better about what was, what were the kernels out of that. And then put that to use in my dissertation. That work, I should say, was still not really cognizant of the implications of competition. And it did not anticipate the particular way in which offer-based electricity markets occur—are designed. It was much more oriented to the system operator putting out estimates of where it anticipated things to be going. And market participants responding to that in a, some sort of tatonnemont process—what in economics is called, I'm not sure if I even pronounce it right, but T-A-T-O-N-N-E-M-O-N-T process.

Ross Baldick (00:25:56):

And then, a while later, it became clearer that a much more practical way for—and that not at all in my dissertation or my research—a much more practical way for information to be provided to the system operator was not a series of experiments, so to speak, by the operator putting out tentative prices or tentative quantities, but rather explicitly having offers being provided to the system operator as some sort of a free commitment to doing—to generating on call based on the results of an explicit market process. So, I think at the time, in the early '90s, lots of people were trying to think about how this was going to work. And so, I think it took quite a while for the consensus to emerge.

Ross Baldick (00:26:57):

At least that's my observation. There may be some who could see it, obviously, straight from the beginning. But one way to view economics is it's an information problem to get information between and across decision makers. And in the case of electricity markets, the information ends up being provided in quite a complicated set of information. I sometimes call it the offer structure, meaning the specification of what the generation asset owners are—what money they want in return for what they're prepared to do. And that they would provide that explicitly to the system operator was certainly not obvious to me, not obvious in Schweppe. I think they somehow assumed that that information would be known by the system operator. The latter part of my dissertation was exploring what happens when it's not known by the system operator, which was certainly a more practical assumption.

Ross Baldick (00:27:59):

But then the "aha" moment for me was to realize that you could just—that other people had thought about this too and had come up with the idea of just asking the generators to specify an offer. I think because I didn't have a background in contracts perhaps, or indeed in auction theory at the time, I think I wasn't primed to come up with that idea. So, that would be, I would say, another place where there were—I had yet to fill in some holes in my economics understanding. There are certainly palpable places where the direction needed better information about economics background. So, my postdoc provided a real opportunity to study some of that economics more carefully and get to understand it a little bit more, not necessarily because that was what my postdoctoral advisor was asking me to do, but because I had enough free time to further do some reading. And as all academics know, graduate studies, or perhaps your postdoc, is the last time you ever get free time to read a book for, you know, for fun, right? An academic book for fun, right? After that, it's all, you know, get the proposal out the door and get the next funding in and get the graduate student onto it. So, that time also gave me some opportunity to learn a bit more about economics.

Julie Cohn (00:29:38):

Dan or Sairaj, would one of you like to jump in with a follow-on question at this point.

Sairaj Dhople (00:29:44):

So, I have maybe a clarification question for you, Ross, is, just for the benefit of our audience, if you could, you know, in your words, describe what you mean by a zonal market versus a nodal market versus offer-based markets and so on, because I, you know, these have been referenced a few times.

Ross Baldick (00:30:05):

Yeah, sure, sure. So, let's start with an offer-based market. An offer-based market—sometimes it's called a bid-based market—but an offer-based market is where generators pass a function to a system operator. And that function is a schedule of minimum acceptable prices versus quantities that the market participant is prepared to honor in terms of their generation. And the system operator takes those offers and throws them into an optimization, whose goal is to always prefer a lower-offer-cost chunk of power to a higher-offer-cost chunk of power in order to meet demand, whether that's forecast demand in a forward market or near-term actual demand in a real-time market. So, the offer is the information that the generator is providing to the system operator on which the system operator bases its optimization of the dispatch.

Ross Baldick (00:31:23):

Now, I said we always prefer a low-offer-cost offer in preference to a higher-offer-cost offer, except when physics gets in the way, and physics can include a number of things, but the most obvious one is transmission constraints. And transmission constraints can preclude us from taking the lowest-offer-cost offer because, to be somewhat colloquial, the generator is on the wrong side of a constraint. In other words, we can't transfer any more power across it. All electricity markets—I think this is true, it may be that some of the markets started with zonal, but effectively all North American markets, I think it's true—all North American markets start with what I think is the standard human approach to dealing with a problem. That is to say, assume it's not a problem and hope it goes away. And in this context, we assume transmission won't be a problem and hope it goes away and run an offer-based market that doesn't pay attention to transmission. The inevitable result in a system that has some transmission constraints, and even in one that doesn't have any transmission constraints to start with,

Ross Baldick (00:33:00):

very soon after you get competition, generators star—investors start building generators in locations you didn't expect them to build. In fact, that's some of the point of competition is for people to come up with solutions to generation supply that the regulated entity had never figured out. If the regulated entity could have figured it all out, why bother with competition? So, the point is going to be that compared to the regulated entity you're going to get generation built in strange places. That regulated entity, because it was typically vertically integrated across generation and transmission, when it planned for its generation fleet, it also planned for transmission. Now that means that with their fleet, they may not have had too many circumstances where there were transmission limits that prevented them using the cheapest generation. A great example of this is where historically nuclear power plants were built, a lot of transmission was built to connect them into the rest of the network, because the last thing you'd want is this cheap-to-operate power—that was very expensive to build, but cheap to operate—being on the wrong side of a transmission constraint, and therefore having to curtail it because you didn't have enough transmission export capability.

Ross Baldick (00:34:24):

So, vertically integrated entities, typically regulated entities or state-based entities, because they were planning generation and transmission at the same time, they could typically make sure that transmission wasn't a problem. So, it was kind of natural to assume that transmission would continue not to be a problem. I mentioned that generation starts building in strange places. But not only that, in the last 20, 30, 40 years, what has happened is that the world has changed from the 1970s when it was, in the '60s, when it was relatively easy to build a big ugly transmission line across lots of area to, certainly, the '90s, but also much more recently, where it's basically very hard to build a transmission line. And there was an existential flip in the world, certainly if we're looking at new nuclear power stations that in the '70s took a long time to build—longer than transmission. Under competition, no one was building nukes.

Ross Baldick (00:35:27):

They were building gas plants that were very quick, relatively speaking, 18 months, two years to build. And if you build them where there isn't enough transmission in a connection—and this became even more prevalent for wind—you suddenly find yourself behind in transmission build out, and you suddenly find that those physical constraints of those transmission limitations are going to limit your action space of what you can do. So meanwhile, the market might have been set up without paying attention to them, but the market doesn't—paying attention doesn't mean that they're not a problem. The system operator has to deal with them. The system operator typically then deals with them through some so-called "out of market process," which is basically some side payments to someone to change their dispatch to be consistent with the physical constraints.

Ross Baldick (00:36:33):

The problem with this side payment, which always starts out with the claim that it'll be really small, it'll just be occasional, it won't be a big deal, is suddenly it becomes a big deal costing a lot of money. Certainly, as soon as the market participants realize that they can get paid to fix the problem that they are causing, okay? So as soon as someone realizes that they can cause a problem and then get paid to fix the problem that they cause, the incentives are obviously not aligned to help the system. The incentives are, if anything, aligned to worsen the system and maybe generation companies forbear against their financial short-term financial interests and didn't actually make the system worse, but it certainly meant that there was a problem. So, most systems then, most system operators, most of the stakeholders, and the government entities, realized that not paying attention to transmission was a problem. And pretty much universally in North America, the first step then—in the ERCOT case, it took about three years, I think, perhaps four years—was to roughly represent transmission, not at the detailed—

Ross Baldick (00:37:58):

The typical system has thousands or tens of thousands of lines, certainly thousands of lines—not to represent the implications of transmission at that detail, but to represent it at a coarser detail. And a typical story is a zonal model that pretends that all lines within a particular geographical area, or a zone, are not a problem, and that the problem just lies in the particular transmission lines that bridge between the zones. In a historical North American context, very often individual utilities who have a specific geographical footprint, they would have a pretty strong system, strong transmission within their geographical footprint, and some connections to adjacent utilities, but perhaps not the strongest—not as strong as their internal connections. So, it was kind of natural to assume that a zonal world, that would probably break along, basically, the historical geographical boundaries of historical utilities, would be a pretty good first cut to represent what are the relevant transmission constraints.

Ross Baldick (00:39:15):

So, everybody gets zonal. Problem then is twofold. One of them is that the so-called inc. and dec. game, that's about getting paid to fix the problem that you cause, shifts from the zonal, the transmission lines that go between zones, to the transmission lines inside the zone. So, if you look at the Texas context, the payments for congestion—to fix the problem caused by limited transmission, prior to the zonal market, most of the action was the inter-zonal constraints. And then it turns out the action shifted to the intra-zonal constraints. Maybe not quite as many dollars, but over time accumulating a large number of dollars, but still there was a problem. So that's issue number one. And issue number two is that the models, by assuming that there is no transmission implications within a zone, basically aggregate all generation assets and all consumption within the zone, maybe hundreds of buses into a single equivalent bus, and tend to assume that the effect on the inter-zonal transmission constraints is independent of the geographical location in the zone.

Ross Baldick (00:40:39):

That's not a correct assumption. So, the incentives even to deal now with inter-zonal transmission constraints, now they'll be embedded into the market process. There'll be different prices in different zones. But those prices, one for each zone, do not have enough information to represent the intra-zonal issues. And so, it's not only that the incentives are wrong intra-zonally, but the incentives are wrong across zones too, because of diversity of geography within zones. So then, after a number of years of accumulating dollars, paying people to fix problems that their generation offers caused, markets then decide that they need to represent as much—or the stakeholders and entities realize that you need to represent—as much of the transmission network into market prices as you possibly can. And the current level of that is that we represent most things related to real power flows.

Ross Baldick (00:41:54):

We don't represent very much at all related to reactive power flows. And some of the things that are related—essentially all of the things related to real power flows are either through a very simplified linearization called the DC power flow, or using a linearization in real-time markets of existing, excuse me, of the current operating conditions. So, the current state of the art in market implementations, with a few bells and whistles to represent losses in certain cases, for example, is basically a linearized representation of real power issues and not much representation at all of reactive power issues. So just to summarize that, we start out with an offer-based market that doesn't represent transmission. Transmission becomes a problem. We do a partial, but by no means full representation of transmission issues into market prices through zonal. And then when that doesn't work as intended or doesn't solve, it perhaps reduces one problem, but doesn't solve all of the problems related to

Ross Baldick (00:43:11):

transmission, eventually, there is a transition to a nodal market. Around the world, there are certain exceptions to that which we could chat about. But generally speaking, unless you represent the geography of generation assets in relation to transmission assets, you will likely have a disconnect between the incentives provided by prices, energy prices on the one hand, and the physical capabilities of the system on the other. And that underpins the greater and more detailed representation of transmission issues into the market prices. And in particular, differentiating or distinguishing prices by bus rather than by just by zoning. Sorry, did that, I'm not sure if that answered all of the questions that you had raised. I hope it answered at least some of them.

Sairaj Dhople (00:44:18):

Absolutely. Ross, thank you so much for that

Ross Baldick (00:44:22):

Pleasure.

Daniel Molzahn (00:44:24):

I had a follow up on some of those questions or some of the discussion, Ross. A really nice explanation. Thank you. So, the way you kind of presented that story is that the zonal markets, you know, was sort of the natural evolution, and then from zonal markets, you know, everyone sort of expected that the next thing would be nodal markets—

Ross Baldick (00:44:44):

Oh, no. First of all, I think of it as a natural evolution. I think you'd probably want to ask other people whether they think of it as a natural evolution, but it is natural to me that, and I think you'd find many people would agree, that it is natural to pick the—imagine that the zones are going to break along what are historical utility lines. I think many of the people who propose zonal markets did not anticipate a nodal endpoint. There are certainly some markets where they do, and I think the Australian market, for example, which is still zonal, the framers of that anticipated nodal as a—nodal pricing as an endgame. But just like Saint–: "give me continence, but not now," they said: “not yet.” It's not the first priority, right? Others, I think, felt that there was eventually going to be a need to go to nodal. So, I don't think it was universal that people thought it was inevitably going to go to nodal, even if, to me now, it is obvious and inevitable that every electricity market endgame is a nodal market.

Daniel Molzahn (00:46:08):

So, then who was, you know, at the time, I sort of just remember right when I was starting in this field, getting some of the discussions that were going on in the space. And I kind of remember it being somewhat controversial, and people had arguments both ways. So, I mean, you sort of made the case here really well for a nodal market. What was the counterargument, you know, when people were saying: "No, zonal market's fine, we should do zonal market. What was their argument based on?

Ross Baldick (00:46:37):

I'm not sure whether computational was made as an explicit argument, but I think it was probably a plausible argument in the early '90s. Okay? I can't remember whether that was part of the argument. I think the main counter argument was institutional complexity, too complicated for the market participants to cope with it. And some of that argument might have been self-serving. They didn't want the complexities of a nodal market, and so they argued that it was going to be too hard. Certainly many, in fact, most electricity markets today in North America still have zonal pricing for loads, in part because the retailers perceive it as too challenging to have nodally differentiated wholesale prices for their retail customers. So, even today, there's an institutional unwillingness to contemplate nodal prices for, let's say, retail, particularly residential retail customers.

Ross Baldick (00:47:53):

And some of that is an equity argument that is to do with: just by happenstance, you happen to be in a favorable position, nodally, versus not being in a favorable position—of course, the same argument applies to thermal generators, but we eventually went nodal for them. So, it's a somewhat specious argument, in my opinion, but I think it's an argument that's applied: too complicated, too difficult, right? What has universally continued is effectively socialization across zones for consumers, socialization across zones for consumers. I think there's, perhaps the perception is it would be just too complicated for customers to cope with different prices that were retail offers that varied by location. You know, somehow, I'm capable of dealing with gasoline prices that vary by location, but, you know, it's just not possible for me to conceptualize, apparently, electricity prices that might vary by location.

Ross Baldick (00:49:06):

That, that's maybe not a perfect analogy. Perhaps a better one would be: I'm able to conceptualize different property values by location, but, you know, just can't do that for electricity, right? In other words, I think they're bogus arguments, but they're ones that are, that are applied. Again, to some extent, they're self-dealing. For a retailer, it's going to be a lot more complicated to set up a world where they have to keep track of for each and every one of their customers. What bus are you taking? What price is the wholesale price of the energy that is being purchased on behalf of your customer? So, I think retailers continue to push back against that. But I think, initially, computational complexity and institutional complexity are the main things. Why have it so complicated? We can get by with a simple, a simplified model that will be commercially adequate, right? That'll be good enough for our commercial model would be a refrain, I think.

Daniel Molzahn (00:50:11):

And do you see that changing going forward as we get more distributed?

Ross Baldick (00:50:15):

Well, I mean, it's completely changed on the generation side. Has it changed for retailers? I don't see much progress. In classes that I've taught since the 90's, I often would say, "well, I would expect within five or 10 years we'll have gone nodal, or much finer-grain zonal, for retail." But it hasn't happened, largely speaking. So, we've got a status quo, some sort of an equilibrium. I think what will change that equilibrium is, as we get more and more load resources, and batteries are a good example now, but I also include consumers that are capable of changing, adjusting their consumption. It becomes untenable to have them being dispatched, so to speak, and dispatched because to help with all constraints, not just the zonal ones, but also possibly the intra-zonal constraints, to dispatch them nodally and not pay them nodally—not—charged for their consumption nodally.

Ross Baldick (00:51:36):

I think it'll become very difficult to do it. Because largely speaking, we have not had a huge amount of demand-side response. We're starting to get a lot more now, and batteries are going to be a big part of that. And certainly, if you can be both a consumer and a supplier, having you exposed to nodal prices as a supplier and zonal prices as a—I think I got that around the wrong place. Having you exposed as battery to nodal prices when you operate as a generator and zonal prices when you operate as a consumer is untenable because of those incentives. When you've only got a consumer who's not mobile and not varying their consumption based on wholesale prices, it's maybe fine to not price nodally.

Ross Baldick (00:52:32):

But as we get any significant amount of price elasticity, and as we find we want to dispatch those consumers on the basis of nodal issues, we're going to find that nodal, excuse me, zonal retail payment becomes untenable. And so, the first step will be to hive out those particular consumers and settle them nodally. That's already happening, I believe, in ERCOT. But the problem with that is, you then will find that it'll become increasingly clear who are the winners and losers of that game. And I think that will then push a lot of market participants to want to be—consumers to want to be settled nodally.

Julie Cohn (00:53:24):

Ross—

Ross Baldick (00:53:25):

Bear in mind that I forecasted this, that this would happen within five or 10 years, 20 years ago, right? So, I may be wrong in my forecast again. So, I'll be more humble this time in my forecast, let me say.

Julie Cohn (00:53:38):

Dan, did you?

Daniel Molzahn (00:53:39):

Really interesting. Julie, I'll pass it back to you.

Julie Cohn (00:53:42):

Yeah. I'd like to know, as an engineer, what was your intervention in this process?

Ross Baldick (00:53:50):

Okay.

Julie Cohn (00:53:50):

From, say, an economist or one of the owners of one of the generating facilities that felt they were not getting a fair deal.

Ross Baldick (00:54:00):

I was engaged as a consultant to analyze the ERCOT zonal market and understand what the implications were of zonal settlement. And I did an analysis, I wouldn't call this serious research, meaning university R&D research for a master's or PhD student, but I looked at the physical issues, the sensitivities of flows on lines to injections at particular points, the so-called shift factors or power transfer distribution factors.

And I observed that the zonal market was already providing incentives that in various circumstances provided quite incorrect incentives for dispatch. I put that to the Public Utility Commission of Texas in a way that was palatable to them. There might have been some Senate hearings as well. I think I gave some testimony at the State Senate, but I can't remember whether it was I think it might have been State Senate people as well as Public Utility Commission people.

Ross Baldick (00:55:27):

But I also presented some of this at the Public Utility Commission. So, the key issue was taking what was, I think, pretty abstruse technical issues, putting them through a lens of economics, the incentives provided by using a zonal model versus a nodal model. And arguing that those incentives were, were rather poor and would be poor, not only for operations, but also for siting of new generation. And again, let me go back to the point that a big part of restructuring is not just about operating the system, it's about getting better capital decisions. So, if you've got the wrong incentives for capital decisions, you are not doing what we really would hope for with restructuring. But bundling—so back from my digression—bundling that technically-based economic argument in a way that was palatable to the senators and to the Public Utility Commission, the PUC people were more cognizant of electricity than the senators.

Ross Baldick (00:56:48):

And so, the discussion was correspondingly more technical to the Public Utility Commission. And making a dent in the perception that the zonal market was working just fine. Okay? It was working just fine. Now, of course, at the time, we were racking up and continuing to rack up the costs of congestion management due to the zonal system. So, there was also the impetus from the fact that a lot of money was being spent. But I think, I would flatter myself, and you might want to talk to other market participants at the time, I would flatter myself that the testimony that I provided was able to get through to people who did not have either the economics background that I had, from learning hard, right? So maybe not even that. And certainly, didn't have the technical background and making a convincing argument to them about an actionable change.

Ross Baldick (00:57:54):

So, again, I'm flattering myself here. You might want to talk to some other people at the time to see whether or not they think it was substantive. But the impression I get is that I made a substantive effect on the decision-makers through that action. And I have to say, neither before nor since have I had nearly as strong and percussive, we might say, effect on policy. It is of some personal disappointment to me that that event, which was about 2003 or so, was somehow the high point of my policy influence. So, some personal regret about that, that I hadn't been able to parlay that into further influence. But having said that, most of the things that then happened for the design of the market in ERCOT, were things that I concur with. There's still things that probably need to be fixed, but that was a huge change that needed to be made. At this point, there's probably not as many things there, they're no longer the sea-change things that need to happen, right? So even though I feel some personal disappointment at not having a stronger continuing influence after that, you know, maybe that was the time to strike and everything since has been smaller beans, smaller bananas, perhaps.

Julie Cohn (00:59:39):

I'll ask a follow-up—

Ross Baldick (00:59:40):

Without denigrating the excellent work of various market participants and stakeholders in in improving ERCOT. I mean, it's changed a lot since then, but I think those changes are incremental compared to the threshold change of going from zonal to nodal.

Julie Cohn (00:59:57):

Do you think there's another sea change ahead with this? As you were saying, there's a customer role to be considered and also distributed generation that is increasingly present on, certainly in Texas and elsewhere on rates?

Ross Baldick (01:00:16):

Yes. I think it's—the biggest change that's going to happen going forward is: the much greater prevalence of renewables is going to necessitate increasing flexibility. You can get flexibility out of flexible thermal generators. But if we're trying to displace thermal generation with renewables, we don't necessarily want to rely on flexibility services being provided by thermal generators that will have to run. I think it makes a lot of sense to try to get flexibility from the demand side. It is a huge sea change for most consumers. Most consumers would not think about providing flexibility to the grid, meaning using or not using electricity on the basis of when it would be convenient for the grid. We are very used to using electricity when it's convenient for us, but there are obviously new things coming down and not so new things.

Ross Baldick (01:01:26):

Electric vehicles is the obvious great example. Their flexibility of charging is due to them having a big battery. But similarly, anybody who has a battery has some flexibility for charging. I think it's going to necessitate—I think it's going to be a sea change. I think it's going to necessitate an actually quite significant change in our market models, which have hitherto mostly assumed in a day-ahead market, 24 almost temporally separable markets. Not quite temporally separable because there are some intertemporal issues. Startup and shutdown of thermal generation and ramping of thermal generation are two specific examples that couple between the hours in a day-ahead market. But they tend to couple a few hours together. I think we will need to explicitly couple all of the hours together.

Ross Baldick (01:02:31):

Why is that? Because when we have a storage device, its state of charge and the changes in the state of charge couple the decisions across all of the hours in the day. And I think this will be a—possibly the together with nodal settlement of load—the representation of state of charge into system operator models is probably going to be the biggest change. And perhaps analogously to nodal markets. But this time I do see an endpoint that's analogous to nodal markets, and that endpoint is the system operator explicitly representing the technical behavior of a battery and explicitly optimizing its state of charge over time horizon. Not pretending that it's a paired generator and consumer, but rather modeling it correctly as a storage device, at least for anything large, "large" meaning more than a couple of megawatts. Most people today, I think, imagine that we can get by with just representing batteries as a paired generator and consumer with some rough, rough and ready representation of the state of charge.

Ross Baldick (01:04:05):

I think that is analogous to the zonal market. It's going to be okay for a while, meaning it's workable, but then it's not going to work very well. And we're going to find that, particularly with very high levels of renewables, price formation is going to be very difficult in such a circumstance, and we're going to need to go somewhere different. And I think that the end point here will be explicit representation of the technical characteristics of storage devices into the ISO model. Just as I would argue that the history of electricity markets hitherto has been the increasing representation of technical characteristics into the market model, whether they're generator characteristics like startup and shutdown and ramping, or transmission characteristics such as transmission limits. In this case, it's physical characteristics of a battery need to be represented, in my opinion, into the market model.

Ross Baldick (01:05:09):

And that, I believe will be the endpoint. And I believe the current kluges are likely to be analogous to believing that the zonal market would be enough. It's not. It doesn't represent the underlying technical characteristics. And I believe we will figure that out in a few year’s time and then start representing state of charge explicitly into system operator models. Now I've already recounted that my forecast 20 years ago to get nodal clearing was not fulfilled. So, you should take any forecast of mine with a grain of salt, obviously.

Julie Cohn (01:05:52):

Thank you. Should we, do you want, Dan or Sairaj, either of you, to ask additional questions on this topic, or should we back up and talk a little bit about algorithms?

Daniel Molzahn (01:06:04):

Well, I have one question that's maybe a transition.

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Daniel Molzahn (01:07:02):

One thing we have seen in discussions with some other interviewees was sort of the convergence of computing technologies and algorithms being able to facilitate the development of markets. And that we had, in the '90s, the increasing computing speeds as well as much better optimization algorithms that really enabled us to run large-scale market-clearing problems. So, what was kind of the, if you can go back to that time, maybe, early to mid '90s when this was developing, we had these computational improvements that were happening. Was it sort of seen as natural that: "yeah, we'll be able to run these large markets, it's clear there's the trajectory of the solver technology to do that," or was that really a big question mark. That we didn't know if we were going to be able to actually optimize these things well?

Ross Baldick (01:08:05):

I don't think I knew. In the mid '90s, I—the story will connect in a moment—lots of other people were thinking about unit commitment and were looking at standard approaches such as Lagrangian relaxation with some bells and whistles. And I spent several years on that. It wasn't very successful. It was pretty hopeless. But I went to a conference in the late '90s. It was set up by Ben Hobbs and Dick O'Neill, and it was called the Next Generation of Unit Commitment Models. And the person who was there was Mr. Bixby from CPLEX. He's now at Gurobi. And he had his laptop with him. There was a unit commitment formulation and a—not a huge problem—but a problem that I—the size of which I had not been able to successfully solve with Lagrangian relaxation type techniques.

Ross Baldick (01:09:21):

And by the way, meanwhile, electricity markets were using linear programs. And Mr. Bixby came back the next morning and he solved it on his laptop using one of the releases of CPLEX. So, it became evident to me at that moment that Lagrangian relaxation was not going to be the right way to do it. That computational advances as set up by CPLEX were in—particularly in the context of integer optimization, but even LP—were going to be the way forward. And it also became clear to me over the next couple of years indeed, that there were all sorts of things that one might want to put into a model, a unit commitment model, and in particular, one that was the clearing engine for the day-ahead market. And that you were always coming up against the two- or three- or four-hour CPU time for day-ahead markets that was going to limit it.

Ross Baldick (01:10:27):

And so, as each computational capability increased—computational capability and improvements in software—we could add more things. So, I think by the early 2000s, it was clear to a lot of people and to me, that what would happen would be, people would think about how to formulate additional characteristics into the model, into models, and that enhanced computational capabilities would enable them to be represented. And perhaps the best example of that was that the first unit commitment models—they had been developed well before the existence of combined cycles. And typically, they would just—on/off models—which corresponded basically to a single fuel and a single cycle generator, which is either on or off. But then once you've got the advent of combined cycles, we had multiple different configurations.

Ross Baldick (01:11:29):

And although in the early 2000s, computationally, you would've shied away from even one binary per generator per hour in a day, 24-hour day-ahead model. You know, that was like the, where you knew you needed to get, but wow, were we ever going to get there? And Mr. Bixby from CPLEX showed that that was true. But then as CPLEX improved, as it was clear that computational capacity was going to get cheaper and cheaper and cheaper, and maybe that had been clear for several years. The combination of improved software, improved hardware meant very rapidly increasing capabilities to solve large LPs and large ILPs. And at the same time, we were getting combined cycles coming into the market who had characteristics that required multiple binaries to represent them fully. That desire to get them better represented in the market—that'll improve the efficiency of operations, improve the combined cycle's ability to operate in the market—went hand-in-hand with the ability to solve larger and larger problems.

Ross Baldick (01:12:43):

So, I think by the early 2000s, it was clear that there was going to be step-by-step better software. And meanwhile, people are going to realize that better software and hardware's coming along, so they're going to keep adding new things into the model, as those things come up as limiting difficulties. I think prior to the 2000s, at least prior to this conference, The Next Generation of Unit Commitment Models, I don't think I had twigged on that. But at that time, first of all, I put away Lagrangian relaxation. I said, I'm never going to bother working on this again. That turned out to be a silly decision for other reasons. But it was clear to me that models such as CPLEX eventually were going to provide this amazing ability to solve problems with integers. Not yet problems with a lot of nonlinearities.

Ross Baldick (01:13:46):

I think we're still at a point where the nonlinearities of power flow are not very easy to fully integrate into a model, but certainly integer linear programming models, therefore representing approximate linearization of transmission issues. And basically, whatever bells and whistles you like in your representation of thermal generators. I think that that's has been growing and will, as needed, continue to grow. Maybe by now the latest representations that include transitioning, timing, and ramp limits between combined cycle configurations, you know, we can already do that stuff in a very sophisticated manner. So maybe that's run its course. But I think the next computational challenge will be representing state of charge into those market models. So, keeping all the things that have gone before: representation of transmission, albeit still linearized probably; representation of multiple binaries to represent multiple different configurations; the thermal generators. And now I think the computational challenge will be to represent state of charge of a large number of battery resources, and that will need computational improvements to get that to work, I think, in a production context. But my working assumption now is, if it won't work this year, within a couple of years, we'll have the computational capacity or the improved software to do it, right.

Ross Baldick (01:15:33):

And the division of labor of that, where Gurobi or CPLEX are building the software and improving it and improving it, and someone else is thinking about the formulation. I mean, back in the '90s, I was thinking about the formulation of unit commitment and trying to build some software to solve it, right? Well, I think it's hard. The division of labor, of having experts building expert general-purpose algorithms, and somebody else doing formulations, is the right way to go. By the way, it underpins my optimization book, which is mostly about how to think about formulation on the basis that someone else is going to take care of the hardware and the particular engine that's going to do the optimization.

Daniel Molzahn (01:16:20):

So maybe a quick follow-up on that. So, if you put yourself in maybe an alternate history where, you know, people were really starting to think about markets maybe in the 1970s or 1980s before we had this competition—

Ross Baldick (01:16:31):

It would've been—you couldn't have done it. It

Daniel Molzahn (01:16:33):

Just wouldn't have worked. Okay.

Ross Baldick (01:16:34):

It wouldn't have worked. I don't think it would've worked. And, and perhaps, and I'm speculating a bit here, some of the reticence to go into zonal and nodal representations with initial markets was a holdover because the people who were around in those decisions had not realized the humongous improvement in computational capabilities that had occurred and that was going to continue to occur. But in the '70s, indeed, I think it would've been impossible. Absolutely impossible.

Julie Cohn (01:17:12):

That's a really interesting insight about the possibility that people involved in the industry hadn't grasped what was happening in the world of computation and software innovation.

Ross Baldick (01:17:27):

I would observe that still people in, in the planning context, this is capital planning, still don't. You know, we've had now 30 years of experience at least of sophisticated operations research, linear programming, MILP software being used in conjunction with extracting information from other software to get constraints, to get representation of the real world, and then have the optimization, do the optimization. We still are doing capital planning, largely speaking, by trial and error. There may be scripts written to automate some of the trial and error, but to the best of my knowledge, maybe there's, there's one tool that perhaps has, one or two tools that have some optimization-based expansion planning in them. And I'm just blanking on the name, although it's at the tip of my tongue.

Ross Baldick (01:18:32):

But largely speaking, the planning is done with a lot of trial and error. And I think there's—that is a holdover of the planners not having on the one hand, not having the observation experience of the capabilities of this software. But on the other hand, it is a challenge because you have to get all of the information from the other parts of the, the real world and linearize it or otherwise represent it in a way that can be thrown into an optimization engine. And it's a real challenge to do that. But I think that is—the fact that I don't see a lot of that happening, that we still see trial and error for planning is indicative that people have not thought hard enough about how to get the—or to automate these processes into an optimization context.

Ross Baldick (01:19:31):

That would be my observation. Now, I may be wrong. There may be some software developers out there who've built some of these tools, some of my graduate students have developed research-grade implementations. But a big problem is getting real world data into the optimization-based implementation. So, I think it was a real triumph to get markets to be able to get an offer from a market participant, to get telemetered data from the real physical world. And then to integrate it all. It's a real triumph. It benefited from the efforts of SCADA systems in the '70s that were data acquisition with some control. And of course, automation was put over the top of it, some level of optimization. But the optimization capabilities were so limited that you wouldn't be—you just couldn't have run the sort of stuff we run today.

Ross Baldick (01:20:40):

So, the software that I think does some expansion planning, it's Energy Exemplar's software, but I've just forgotten the name of the software. It's a very well-known, widespread, used software. I think they have some automated optimization-based expansion planning, but I don't think it has become pervasive in the way that the optimization in markets, the electricity markets, has become absolutely pervasive.

Julie Cohn (01:21:10):

Do you think any of that can be attributed to increasing specialization on the part of people who in academia are thinking about power systems? Because as more and more people take on this really complicated system and think about, "what is my contribution," they have to specialize. And do you think that resulted in, in some of the advancements?

Ross Baldick (01:21:39):

Well, I said I, I wasn't able to be both formulating a unit commitment problem and building the software. So, I appreciated the specialization there. Particularly because the specialization resulted in such high-performance software that we could then come back and use it. But to your point, I think there are a lot of people in the industry who have, who are just not acquainted with modern operations research. So, it's a hole in their educational knowledge base. I don't think you need to be an expert in it, okay. To know that it exists, and it has great capabilities. Okay? So, I remember a student of mine came back from talking to some utility types about automated transmission planning software. And they were astonished, apparently, that the software could figure out that if you wanted to connect point A to point B, and you had some candidate segments of transmission, that you had to actually add segments that went all the way from point A to point B.

Ross Baldick (01:22:50):

They couldn't conceptualize that you could write down an optimization formulation that would instantiate that, and the result would be, well, out of these hundred candidate line segments, if I really want to connect from point A to point B, you would pick these particular segments. So, there was, evidently—this is a few years ago, this is more than a decade ago now, I should say—there was evidently a lack of understanding that you could write this stuff down and get it to work, right? So, in that sense, I think it represents a lack of access to probably just a couple of simple operations research examples would've provided the light to go, "oh, yeah, I can see that that works. So now let's think about that."

Ross Baldick (01:23:47):

The other side of it, though, in the transmission expansion context is, if you really want to apply optimization, you've got to have a lot of candidate line segments, which means you've got to have done a lot of research about where you can build the lines. And unless you automate that, it becomes very difficult to imagine that your transmission guy is going to come up with 300 segments, of which I'm only going to use 10 of them to get from point A to point B. Right? Transmission planner guy is going to say, well, I'm just going to build it here. Right? Because the effort to come up with the 300 segments is very huge. So you also need to automate that. So what I would observe to you is that there needs to be a number of things automated to make that sort of thing work.

Ross Baldick (01:24:39):

And in the case of markets for operating the system, we already had a history of supervisory control and data acquisition with the inklings, with energy management systems, of automated control over the top of it. So adding that the automated control or the directions of dispatch would be the outcome of a market was maybe just one more domino. Right? One more domino to make that work. Whereas automated expansion planning— there are multiple elements, as I see it, that need to be automated to make it work. And it's not clear to me that there's been motivation to make those elements automated separately, but in a manner such that you can transfer information from one—. So to use my example, again, I need a piece of software that generates candidate line segments based on demographic data—too close to humans, don't want to cross a river, want to go along a right of way—to generate hundreds or thousands of potential segments, and then have that information through—connect that to a routing optimizer that's informed by generation expansion plans, or is integrating generation expansion plans.

Ross Baldick (01:26:06):

We've historically done all these things separately. We haven't got a unified way to talk between those pieces of software. So I think there are some institutional challenges. Can't just blame it on the D.O.U.G.s—the dumb old utility guys—not knowing about operations research. There are some, I think, challenges, particularly relating to, they need to be multiple things that come together, to make this work better than the transmission guy or gal, but more typically guy, coming up with the one or two or three, not segments, but complete routes and taking that to the public utility commission. So, there's an institutional barrier there. I would observe that when that transmission planner dies or retires, very likely they have not passed on their institutional knowledge to the next person. And that's when we really should have built the software to help us, because, while that person was still around, we could have been developing the software and talking to them and understanding what their thought process was, with a view to using operations research techniques to automate it and systematize it.

Ross Baldick (01:27:31):

But if you wait till that person retires, then you—which is a problem throughout the electricity industry. Not in renewables, but in what we might think of as the historical parts of the electricity industry—that we have retirement, and I think, sadly, we don't necessarily have the transfer of knowledge from senior people to juniors. And that, I'm afraid, in the transmission context, has been exacerbated by the fact that the traditional utilities have largely ceded a large fraction of, but not all, transmission planning to the system operators. And the system operators have taken on transmission planners [*planning*], but they have not got a historical memory of doing transmission construction because they didn't do it until recently. And so I think there is a challenge there of how do we get that to work? I would advocate for optimization-based automation of some of this. But so far, I haven't been able to make that argument into an actual, we might say, protocols or approaches. But we need to get some of those ideas made into something that we can pass on to the next generation before those people retire and then knowledge becomes inaccessible.

Julie Cohn (01:29:07):

So this may come as a shock to all of you, but we've actually been chatting for nearly an hour and a half already. I know there's some time constraints for Daniel. So, I guess perhaps to close out this conversation and add your final thoughts to the record, we've talked a lot about topics that the general public probably doesn't understand but affects them quite directly. So, I guess my question to you is, what would you want the general public to understand about the kind of work you've done and your contributions to the industry?

Ross Baldick (01:29:53):

I think I'd like the general public to understand that although I have worked as a consultant for particular entities, who obviously are paying me to make a spiel, most of the research that I have done has been aimed at public interest. How do we better integrate renewables? How do we better run the system? How do we better plan for fixed assets such as transmission that we're going to have around forever, and which have obvious deleterious effects on neighbors? How do we think about planning that in a way that has the greatest benefits, least cost or greatest benefits minus costs? So, I think I'd like the general public to understand that the things that I've worked on, I've in part chosen because I think they have public interest. That doesn't mean they've always panned out and been utilized by the public.

Ross Baldick (01:31:02):

But that, that work has, has always had at its background fundamental question of: to the extent that we can affect welfare, by which I mean benefits minus costs, how can we arrange things so that welfare is improved? So that would be, that my underlying motivation has been in that that context. That is not necessarily, although it's obvious to me that we should plan to maximize welfare, it's not, I think, obvious to a lot of people within the electricity industry, for example. But that's, that is an abiding guiding principle that if you are going to build something or set up a structure, it should be, it should abide by that. Of course, I can't say that everything I've ever done has improved welfare, but that has been the abiding principle. The second thing that I would say is that there is a lot of technical complexity in the electricity industry.

Ross Baldick (01:32:04):

And that technical complexity has to be respected. And a lot of it, it takes quite a lot of effort to understand it fundamentally. And so, I don't want anyone in the general public to sort of just tacitly accept that everything I'm saying is going to be good, or that I'm always a good guy. But to recognize that, to adjudicate what I'm saying, needs technical capabilities. And I think it's very important to have competition of ideas where I'm forced to argue my position against someone else, although I might always prefer not to do that, right? But that's very important. Having technical experts, preferably those that can articulate the technical points in a way that is palatable, particularly for non-technical speakers but, to non-technical background people.

Ross Baldick (01:33:10):

But to recognize that there are technical issues that really are very hard to explain. And it's not always that I'm being patronizing when I say, I really don't think I can explain this to you, right. As, as much as that can be a patronizing thing to hear. And the best example I have of that is reactive power, which is something that is very, requires a lot of technical background to get the point. And those sort of concepts exist and need to be well thought out. And finally, I think I would say that certainly in the last 20 years, a lot of my research, consistent with understanding that decarbonization is an important part of our welfare as humans, has been aimed at trying to think about how to make sure we can integrate the very high levels of renewables in our electricity system.

Ross Baldick (01:34:18):

And I think that's certainly an abiding thing that I think the general public should understand, that there are technical issues there, and that my work has aimed at trying to help that, whether that is directly relating to renewables or, for example, in understanding how our system operator could better integrate storage. We were talking earlier about representation of state of charge, system operators can better represent storage with a view to them providing flexibility to help with even higher levels of renewable integration. So, a lot of the lens for me in the last 20 years has been how do we facilitate renewable integration? And that may not just be building the windmill, or the wind farm, or building the solar farm, but rather, how do we get the system to continue operating in a world that has high levels of renewables?

Julie Cohn (01:35:26):

Thank you.

Ross Baldick (01:35:26):

That's maybe it for the general concepts. I might have missed a couple there, but I think that would be the abiding things I would like the general public to understand about my work and what I believe has been my strongest contributions.

Daniel Molzahn (01:35:42):

Julie, can I ask, I know that was supposed to be the last question. Can I ask one more question?

Julie Cohn (01:35:47):

Always.

Daniel Molzahn ([01:35:47]()):

So, Ross, one thing I really appreciated about the discussion you had earlier was about how you're able to translate technical details to policymakers and this transition from zonal to nodal markets. And you had to convince senators and their staff members about this. And so, you know, this is something I tried talking with my students about is, how do you translate complicated technical concepts to those audiences? And you're just saying that this is hard and sometimes they should recognize your expertise, right? But if you were talking to students and saying, you know, if that's a path you want to go down, is to be having an impact in policy making, and in decision making, and in this sort of thing, or even just in normal—you know—a career as an engineer, you have to present to business folks and these sort of decision makers. Do you have any advice for students on how to learn how to do that and how to do that well?

Ross Baldick ([01:36:50]()):

Well, I think the most valuable class that I took in graduate school was a technical communication class. So, I would definitely advocate for technical communication. As you know, Daniel, many of our graduate students are not native speakers of English. And improving their spoken English skills will significantly help them to make a policy case because, unfairly as it may be, if you're accented, and strongly accented, you are going to get ignored in most lay contexts, let's say. But for everyone, I think a technical communication class. And I would say that my ability to communicate with the state senators and other lay people was significantly enhanced by having taken technical communication. But it takes more—technical communication class—but it takes more than that. You need to practice it.

Ross Baldick ([01:38:12]()):

Try out ways to explain things and see if they work. In other words, like any skill, it takes some effort and taking your great research and at the last minute, trying to think about how to express it in English is probably not the approach. One needs to practice it, meaning probably refine and change the way you explain things based on trying it out on a willing Guinea pig and seeing if they can understand it. Something I'll add is that if you build up an ability to explain some of those technical things, then the person listening to you may be more prepared to give you the benefit of the doubt. When you say look, I don't know that I can explain this other concept. Can you take that one on trust from me?

Ross Baldick (01:39:11):

Now that could be an invitation for all sorts of baits and switches or scams, but I think it's, it's in the nature of human interaction that if you were to build a rapport by being able to explain some concepts, that will help you to be able to make your technical case for more difficult concepts, even if you are not fully able to explain it in the very simplest language, or even if it's just not possible to explain it in the very simplest language. So that's a human interaction issue, is building up confidence that—in your listener—that you are trying your best effort to explain something, and that you're not hiding something from somebody by not being able to explain something technical. Right? That's perhaps the most important part of building up—being able to explain simple things and building up a rapport with someone listening to you. I hope that was at least partially responsive to your question.

Daniel Molzahn (01:40:19):

That's great advice. Yeah. I think that's good advice for any student and for faculty as well.

Ross Baldick (01:40:27):

Yes, for faculty as well.

Julie Cohn (01:40:30):

Any other questions, Dan or Sairaj, before we say thank you?

Daniel Molzahn (01:40:38):

Not on my end. I mean, I have many more questions. I always enjoy talking with Ross, but no more tonight.

Julie Cohn (01:40:46):

Okay, great. I'm going to end the recording now.

*[End of interview]*