Algorithms & Power Systems Architecture:

Using Historical Analysis to Envision a Sustainable Future

Oral History Project

Interviewee: Daniel Kirschen

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***Abstract*:**

Daniel Kirschen, Ph.D. discusses his educational background in Belgium and the United States and his professional experiences in power systems engineering in the UK and the United States. He discusses his contributions to the design of power markets, including his decision to publish a textbook on economics in power systems. He describes working at Control Data Corporation (CDC) in the 1990s, developing power flow and state estimation software. He explains his decision to move to the University of Manchester, influenced by his wife's interest in Morris dancing. He discusses the difference between research and development at a company like CDC and at universities. He describes several CDC projects including an expert systems package that was a technical success, but a market failure. This is a theme that recurs throughout the interview. He offers a motto for the challenge to system operators: "balancing the greed and the fear." Dr. Kirschen further explains that in the 1990s, utilities needed specialized software, whereas later standardized software became affordable. He shares an anecdote

about comparing linear programming optimal power flow with non-linear power flow for Pacific Gas & Electric (PG&E) in the late 1970s. He talks about state security and economics of power markets. He reflects on differences between work in academia and industry, and collaboration between the University of Manchester and National Grid. He discusses with Dan Molzahn nonlinear and linear solvers for optimal power flow, addressing mathematical concepts, software innovations, and computing capability as influences. He distinguishes between the problem formulation and the optimization engine as steps in solving. He reflects on the advent of power markets and the greater need to optimize operations. He further speculates about optimization challenges as more distributed resources join grids. He discusses his decision to move to Seattle and join the University of Washington. He reflects on which of his published papers were most influential, noting that his most cited paper was not much used by industry. He mentions his most recent ventures – becoming editor of the IEEE Transaction on Energy Markets, Policy, and Regulation, and publication of his new textbook, *Power Systems: Fundamental Concepts and the Transition to Sustainability*. He briefly discusses the transition from analog to digital computers and how they are used in power system simulations. Returning to the topic of markets, he underscores the importance of market participants in influencing the efforts of system operators to optimize the grid. He closes by encouraging students considering the field of power systems engineering to balance the three objectives of keeping the lights on, saving money, and integrating renewables.

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 (00:00:00):

This is Julie Cohn. I'm conducting an interview with Daniel Kirschen on July 22nd, 2024, at the Seattle Convention Center in Seattle, Washington. Sairaj Dhople will assist with the interview, and Jess Slater is also participating in this interview and may ask questions. Dr. Kirschen, during today's interview, we're especially interested in your early work on system optimization and control, and how this later was carried forward into industry standards. But we're also very interested in the transition of your work to a focus on markets. Before we address those topics, though, first we'd like to begin with an introductory

conversation. Could you please describe your educational background and your professional positions in the fields of power systems optimization, control, and markets?

Daniel Kirschen (00:01:08):

Thank you very much for interview today. I'll be looking forward to this conversation. So I did my undergraduate education in University of Brussels in Belgium, and then I obtained a fellowship for the Belgian American Educational Foundation that allowed me to continue my graduate education, University of Wisconsin, Madison, where I specialized in electric machines and drives. On graduation, I took a job with Control Data Corporation in their energy management system division in Indianapolis, Minnesota, where I worked for, from 1985 to 1994. And partway through that time Control Data, this division of Control Data was bought by Siemens, the big German conglomerate. I worked at Control Data and Siemens until 1994, which I went to an academic position in University of Manchester Institute of Science and Technology. I stayed until 2011. Since 2011 I have been at University of Washington in Seattle.

Sairaj Dhople (00:02:17):

So, Daniel, machines to start with. And then Control Data. Was that a deliberate switch or just the flavor of the times?

Daniel Kirschen (00:02:26):

I had taken all the classes in power systems with Fernando Alvarado, and I didn't really like the idea of working in industry on machines and drives. I was more interested in the mathematical side; it seemed some more interesting to me.

Julie Cohn (00:02:43):

So would you characterize yourself as more of an academic or somebody who's straddled multiple worlds?

Daniel Kirschen (00:02:53):

I always wanted to be an academic. I feel much better in the academic world than in the industry world.

Julie Cohn (00:03:05):

I think we'll turn directly now to your contributions to both optimization and control of power systems. When you look back, what do you consider to be the most important technical problem you tackled?

Daniel Kirschen (00:03:24):

I think my, I like to think my biggest contribution has been in the area of markets. It's not technical contribution but more explaining how markets work to electrical engineers and making, helping them understand the economics of markets. I, on the, on the way, I have done some scientific technical contributions on security assessment.

Julie Cohn (00:03:57):

I noticed that the title of the book that you published, I think it's 20 years ago this year, is that correct? 2004. Had to do with economics. And your training is as an engineer. So could you talk a little bit about an engineer's perspective on economics?

Daniel Kirschen (00:04:16):

Well, I have economists in my family, so that it wasn't too hard. And I had taken some economics as an undergraduate. And then when electricity markets appeared to become important, and I just trained myself in economics, I took a textbook and read a textbook and parts in economics and learned enough about economics to make sense out of it. And then I had my colleague, Goran Strbac, and I had long conversations over coffee discussing economics and how to make sense of economics in power systems.

Sairaj Dhople (00:04:52):

Daniel, maybe this is convoluting the timelines a little bit, but a lot of people that we've talked to have mentioned Control Data. Can you tell us a little bit about what Control Data was doing in the '90s and why so many of the people that we know and hear about in the power systems that are today are associated with it in some way or form?

Daniel Kirschen (00:05:16):

It is an interesting point. I also noticed that a lot of people who were there at that time have been doing quite, quite well. I think that what happened is that people were interested in power systems. You had the opportunity; you go to work for utility. But okay, utility work is a bit boring. It's quite repetitive. So if you want something intellectually more challenging, you went to work for either Control Data, or at the

time ESCA. That became Alstom that became GE. That's where the intellectual challenges were. So it attracted a number of really talented people to work there.

Sairaj Dhople (00:06:03):

What were you guys building there? Was it software? Was it, were you working on more theoretical algorithms? What was going on?

Daniel Kirschen (00:06:11):

What was going on? Well, so in a sense, it was a pioneer. They were building systems, computer systems, and Control Data had the advantage that they were part of a computer company that was doing really powerful mainframe computers. So the big application software, power flow, state estimation could run faster on those big mainframe computers. And a lot of the work, what most people were doing was working on projects for a particular utility. So pulling together the software and making it work for the particular utility. I was on a very small R&D team that were working on new applications or refining the application.

Sairaj Dhople (00:07:03):

Who else was on your team?

Daniel Kirschen (00:07:08):

On that team? Well, Bruce Wollenberg was, was the leading light of that team at the time. Hans Van Meeteren was my boss. Jim Waight, which was also my boss for a while. Jim Frame.

Sairaj Dhople (00:07:26):

Bruce is maybe the most recognizable name, for me at least.

Daniel Kirschen (00:07:29):

Yes, definitely. He was, he was an inspiration to the rest of us.

Sairaj Dhople (00:07:34):

And then what prompted your transition back to academia? Was it always something that you wanted to do? And why Manchester?

Daniel Kirschen (00:07:41):

I was tired of industry. Different things happened. I had a new boss with whom I wasn't getting along, and there was conflicts. And then the—we had been bought by Siemens and that was, there was a turf battle between the Siemens team and the Control Data team. And so that was getting boring. And I wanted to go back to academia.

Sairaj Dhople (00:08:09):

And why Manchester?

Daniel Kirschen (00:08:11):

? Have you heard of a British form of folk dancing called Morris dancing?

Sairaj Dhople (00:08:21):

No.

Daniel Kirschen (00:08:24):

Well, my wife was part of a Morris dancing team in Minneapolis, a women's Morris dancing team in Minneapolis. And there was another Morris dancing team, which was a men's dancing team. And the men had gone to England to go and see how it's done in the home country. And the woman decided: it's our turn to go. So we had a baby who was nine months old, and while my wife was dancing, somebody needs to hold the baby. So I went along. And we started in the south of England and made our way progressively north, dancing with different teams. We went up north and we ended up somewhere not too far from Manchester in a place called Wigan. And it was a beautiful Saturday afternoon as occasionally happens in England, and we had a wonderful time sitting in the pub and being treated really well.

Daniel Kirschen (00:09:16):

So I had a good memory of that part the world. And a few months later, I'm sitting at my desk being pissed off at my boss when I get this email from Ron Allan saying, “Hey, we're opening a position in the University of Manchester.” If it hadn't been for Morris dancing, I would have thought: not in England. Boring, delete, never thought about it then, ever again.

Sairaj Dhople (00:09:38):

Who was this person you mentioned? Ron Allan, you said?

Daniel Kirschen (00:09:40):

Ron Allen, he was a professor at University of Manchester in Computer Science and Technology. Have been retired for quite a while now.

Julie Cohn (00:09:49):

So was it unusual that there was an intellectual, theoretical group working at Control Data, or was that typical of other computer development companies?

Daniel Kirschen (00:10:05):

I think every, every company that was in this business had a few people working on new applications. But it's not like they had big R&D projects. It was very difficult to—those teams we were in remained quite small compared to the people working on the projects. Because they, it's not a highly profitable business, and utilities were not particularly trusted in the developments. They wanted <inaudible> systems that worked. So, we were trying to, sometimes getting the feeling, it was a bit frustrating because you would get a bit of feeling, you're developing some really exciting new stuff and the utilities are, they say they're interested in it, but then they never have the resource to actually put it in practice. The case in point was the optimal power flow. Everybody was working on optimal power flow at the time, and the utilities, you—the—you would deliver the computers to new control center, to them, and they would have so much work to get it working that by the time they got to the optimal power flow, they would try it a couple times and then the operator would not be particularly interested in it.

Daniel Kirschen (00:11:31):

They didn't feel like they really needed it.

Julie Cohn (00:11:36):

And these were still vertically integrated companies?

Daniel Kirschen (00:11:39):

Vertically integrated utilities.

Julie Cohn (00:11:40):

So their main concern with the systems you were installing was preventing, managing, keeping the system stable, preventing outages. They weren't concerned about optimizing?

Daniel Kirschen (00:11:54):

They were, they were, they would try, but they were not under tremendous pressure to save the last penny. Or having to prove to somebody that they had the best possible solution.

Julie Cohn (00:12:09):

Did your research team collaborate with anybody outside of CDC at either a university or a private company?

Daniel Kirschen (00:12:15):

Well, they—there was another big research project, I was not involved in that was a collaboration with EPRI, or E-P-R-I, they like to be called. On the operator training simulator. That was another really big effort that happened.

Julie Cohn (00:12:35):

But your group didn't collaborate with a university in particular, or?

Daniel Kirschen (00:12:39):

There was something called the orthogonal state estimator that stemmed from academic work, and I think we sponsored a PhD student who ended an upcoming and working full time company and take his student prototype into product.

Julie Cohn (00:13:07):

And that became something the CDC sold?

Daniel Kirschen (00:13:11):

Yes.

Julie Cohn (00:13:14):

So what was the path from optimal power flow to markets? Was it a straightforward step??

Daniel Kirschen (00:13:23):

Well, in between I did quite a bit of work on expert systems. I did work on expert systems from power system restoration. We tried to put together a package that would be an intelligent system, but it was a nice piece of software, but it didn't really hit the markets. Nobody was really interested in it. So again, the utilities would enjoy looking at it, but then they were really, were unwilling to put in the money to make it happen in practice. Substantially a technical success and a market failure. So what happened with markets is that people started talking about markets, markets in California, and just before I left Control Data and Siemens, we had to start having some meetings discussing what does this mean? What kind of products do we do we need to come up with? And then I left.

Julie Cohn (00:14:31):

Did CDC come up with, or Siemens I should say, did they develop the types of software that utilities started using, or grid operators, I guess.

Daniel Kirschen (00:14:41):

Yes. That was after I left. They had an offering. So did the other competitors. They all had to do that. My understanding is it became a more profitable business because, the utilities really had to spend the money to make it happen. Before that they were pinching pennies.

Julie Cohn (00:15:01):

So, you left, you had reasons to go back to academia, and you had begun some work on the concept of a power market, a wholesale power market, I assume.

Daniel Kirschen (00:15:15):

Right. I didn't really work on market engines for some reason. I started being first interest in probabilistic methods for security assessment.

Julie Cohn (00:15:26):

Can you describe that a little bit, for the non-technical, non-theoretical listener?

Daniel Kirschen (00:15:33):

Well, the traditional way, which is still the way it's done mostly is to say: we want to make sure that if one bad thing happens in the power system, a power transmission line fails or whatever, the system is, remains stable. Without looking at either the probability of that happening, or the consequence of that happening. And the more mathematically rigorous way of looking at things is to say, well, not all transmission lines have the same probability of failing and not, they don't all have the same consequences. So if you want to keep the system secure at minimum cost, you should really look at it in terms of risk, which I define as—essentially in simple terms—were the product of probability and consequences.

Sairaj Dhople (00:16:36):

So was this work that you carried out in Manchester?

Daniel Kirschen (00:16:38):

I did that in Manchester, yes. In collaboration with National Grid.

Julie Cohn (00:16:42):

So it's both a technical and an economic question, it sounds like.

Daniel Kirschen (00:16:47):

I like to see running a power system as balancing the greed and the fear.

Julie Cohn (00:16:53):

Balancing the greed and the fear.

Daniel Kirschen (00:16:57):

Balancing the greed and the fear. That was my motto for a number of years. And then recently, since I moved to Seattle, I said balancing greed and the fear and wanting to be green. So just even more interesting. And I like to say, you can be secure and cheap, but you won't be green; you can be green and secure, but it won't be cheap; or, you can be green and cheap, [but] you won't be secure. So balancing all three.

Julie Cohn (00:17:26):

Interesting. It's a tripod.

Daniel Kirschen (00:17:27):

It's a tripod

Julie Cohn (00:17:28):

Yeah. Let me see, Daniel, did you want to ask any questions at this point?

Daniel Molzahn (00:17:34):

I did have one question. So you had mentioned Daniel at Control data that you were on the R&D team, but there were other teams that were doing more utility-specific tasks. And I'm curious, were those tasks that those other teams were doing pretty much the same across all utilities? Or was there really a lot of customization involved? And if there was customization involved, what was that, what made it different from one utility to another as to what the requirements were?

Daniel Kirschen (00:18:07):

It was. I was not really involved in a lot of that, so I can't give you a whole lot of details, but a lot of utilities wanted what they call "specials." They have their own little way of doing things. Sometimes it was algorithmic, sometimes it was little things about the color of the displays. There was always a tension between the salespeople, who loved the specials because they could charge extra for that. And the project people would say, oh, special, that's more work and that, that makes life difficult. And it turned out doing specials is actually a bad idea because you spend a lot of resources dealing with little things that you don't get to replicate for other people.

Daniel Kirschen (00:19:00):

It is interesting. Bahman Hoveida, you may have heard of him, who was at Control Data for a while, and we overlapped for a while, and then he left. And then he created Open System International, and he essentially took the approach that what he wanted was a basic, very standardized system that he could sell for cheap, no specials. And smaller utilities were happy with that because they could get a system cheaply and they just had something that really worked. And he built that into a billion-dollar company that he sold recently. So he would be an interesting person to talk to. You have him on your list?

Sairaj Dhople (00:19:47):

We have been trying.

Daniel Kirschen (00:19:48):

He's local.

Sairaj Dhople (00:19:50):

He is—

Daniel Molzahn (00:19:53):

That's really interesting. Thanks, Daniel. I guess maybe one quick follow up on it was, were there any of the kind of special customizations that people did? Do you know if any of those ended up being kind of conceptually or technically interesting—went on to inform broader questions that people did? Or was it really just kind of a—this is how we do things here and it's a little tweak of something

Daniel Kirschen (00:20:20):

Off the top of my head, I can't remember something that was,

Daniel Molzahn (00:20:24):

There's nothing kind of obvious that was a big insight from some customization that got widely adopted? That wasn't really a thing that happened.

Daniel Kirschen (00:20:36):

Not that I can remember.

Daniel Molzahn (00:20:38):

Oh, interesting. No, thanks.

Daniel Kirschen (00:20:40):

Now that brings to mind something that I was involved in that was truly quite interesting, was the OPF [optimal power flow] testing we did for Pacific Gas and Electric. So PG&E was interested in buying a system from us, and that was a big deal because they're a big utility, very, pretty technical, and they wanted an optimal power flow. They had an optimal power flow inhouse that was a nonlinear optimal power flow. And what we were offering was a linear programming-based optimal power flow that was developed by Brian Stott and Ongan Alsac. And they were not convinced that this LPOPF [linear programming optimal power flow] was going to work for their purposes because it was handling the

active part of the problem separately from the reactive part, and then possibly doing some iterations between the two. So they gave us some test cases that they wanted us to run on both systems. And comparing our solutions with the solution that they had from their cases. Unfortunately, the translation of the data hadn't been done properly. So we spent months trying to figure out why this LPOPF was not actually working properly until finally we found out where the problem was and showed to them that it was actually working very well and considerably faster than the nonlinear optimal power flow.

Julie Cohn (00:22:15):

Did you have to reload all the data in to do that?

Daniel Kirschen (00:22:20):

Well, they had to do a translation program because it was messy at the time. At the time there was really this concern about the time it took because computer resources were still considered very expensive and getting things to go faster was always a concern.

Julie Cohn (00:22:40):

So around what year might that have been?

Daniel Kirschen (00:22:46):

Yeah, would have been five, would've been '78. I saw that you have Alex, but Alex you can ask my counterpart at the time.

Julie Cohn (00:23:00):

So having proven that you had a better OPF, did that test lead CDC to be able to sell it to more utilities?

Daniel Kirschen (00:23:18):

Yes, it did, but again, it was—we would sell them and they wouldn't really use it.

Julie Cohn (00:23:22):

Oh. All right. But we still haven't gotten you from your probabilistic work to your market work.

Daniel Kirschen (00:23:32):

Well, the two happened kind of the same time. Because this duality between state security and economics is—it's an ongoing view. Economists don't really understand the security aspect of the power systems. So, and we felt that there was something there we could explain carefully that: yes, you have the basic economics 101, but it gets more complicated when you're running a power system. When you have those externalities under consideration that has to be taken into account. So that led to a lot of conversation with Goran Strbac and gestation of the idea of writing a textbook on power system economics.

Julie Cohn (00:24:25):

And is that now used in business schools as well as engineering?

Daniel Kirschen (00:24:30):

I would say more on the engineering side. The economists don't like to look at the engineering. They don't understand the engineering

Julie Cohn (00:24:40):

Well, do you think they do a better job now of incorporating questions about reliability in some way?

Daniel Kirschen (00:24:49):

I think they realize they got so much pushback from the engineers that they have to be aware of that.

Julie Cohn (00:24:58):

But is there a, not being an economist or an engineer, my question is: If I were to take an approach from your book, would it be different in kind from the way an economist would approach developing a market design?

Daniel Kirschen (00:25:17):

No, I think the market design, we kind of agree on the way the market should work, just the difference in the emphasis. They are interested in different problems than the engineers are. For the engineers, the first question is: are the lights going to stay on? The economists are going to save the last penny. Pushing from two opposite directions.

Julie Cohn (00:25:42):

And what—go ahead.

Sairaj Dhople (00:25:43):

How different was it being in academia in Manchester versus your job in CDC? Or were the boundaries between industry and academia not as marked as they are today?

Daniel Kirschen (00:26:04):

Well, the—personally I enjoy being an academic because of the freedom of being an academic. You are your own boss. And something that struck me after I finished my PhD and started working for Control Data is that when I was doing my PhD, I was pursuing ideas working for myself. And then I was working in industry, working to make money for the shareholders. Definitely not as satisfying. So going back to university, regaining that freedom, pursuing what was really interesting to me.

Sairaj Dhople (00:26:47):

And what was the driving force behind the types of problems you picked up on in Manchester when you first arrived?

Daniel Kirschen (00:26:55):

Curiosity. What I was interested in.

Sairaj Dhople (00:26:58):

You mentioned some collaborations with National Grid?

Daniel Kirschen (00:27:02):

Yes. National Grid was—they have some good people at National Grid and we needed some data. We wanted to work on relevant problems, and they provided us some data and gave us some feedback. And there was a funding mechanism that required us to collaborate with National Grid.

Sairaj Dhople (00:27:23):

So you've been in that position where you directly pushed products and ideas in your role in CDC, and then transitioning to academia. You also worked with these guys or industry in general. Did you have an easier time getting your ideas implemented in one position versus the other?

Daniel Kirschen (00:27:44):

Actually the two were a bit similar because it's—when I was at Control Data, we'd come up with these new ideas of products and then we would have to sell them to utilities, and then in academia we would come up with these new ideas of products, and we would have to sell them to utilities. Same kind of: eh, nice, nice, interesting. But we're not quite interested enough to put a lot of money into it. It was a question of having to be really patient and take time for ideas, then make their way in.

Julie Cohn (00:28:21):

What were the venues where you proposed the ideas? Were they direct meetings with industry? Were they conferences like this?

Daniel Kirschen (00:28:29):

Both. We would just meet with National Grid, we would meet the utilities, and present papers at conferences. and write papers in journals.

Julie Cohn (00:28:39):

Where did you get feedback on the ideas you were presenting that was interesting or useful or annoying or whatever?

Daniel Kirschen (00:28:51):

Those, those meeting with National Grid, some of the engineers were top notch and they'd tell you: "That makes sense." "That's not really the way to do it."

Julie Cohn (00:29:00):

Oh, interesting. More so than say in a conference setting.

Daniel Kirschen (00:29:06):

I think in a conference setting we're a bit more gentle with each other.

Julie Cohn (00:29:11):

Interesting. Is that true across disciplines in this general field?

Daniel Kirschen (00:29:20):

I don't know.

Julie Cohn (00:29:25):

Daniel, any other questions at the moment?

Daniel Molzahn (00:29:28):

Well, I did have one follow up on this comparison with the LPOPF versus the non-linear OPF. I was just curious maybe this is too technical of a question, but I'm very curious was PG&E—what was the form of the nonlinear algorithm that they were using? It was do you happen to remember what—I'm just curious how the LP version beat it and if you think it still would nowadays.

Daniel Kirschen (00:29:55):

I was trying to remember that the other day. Don't remember exactly where, which OPF they were using. I think it was the one done by GE at the time. Some kind of Newton OPF.

Daniel Molzahn (00:30:21):

I guess the reason I ask is, it would've been right around that time I suspect that some of the interior point methods were starting to be developed.

Daniel Kirschen (00:30:29):

Right.

Daniel Molzahn (00:30:29):

But I don't think they were applied in that setting yet.

Daniel Kirschen (00:30:32):

I think was it was a bit before the interior point methods.

Daniel Molzahn (00:30:38):

Yeah. That, that would be my guess is that they weren't there yet. And I'm just curious for your perspective, how has that evolved over time? Like these ideas coming out of the optimization community with kind of interior point versus active set solvers and the linear programming methods.

Like how, just what's your perspective on, I'm curious, how it all came together and also what—how that technology has impacted the state of the art.

Daniel Kirschen (00:31:12):

What was interesting is that in those days, you had some smart power system engineers who would take what the mathematician came up with and apply it to power systems. What made a real difference is when those software packages started being implemented and they could be used as is and suddenly stopped having to customize the optimization package for power systems.

Daniel Molzahn (00:31:44):

I see. It was that, around that time that I suppose you're talking about kind of CPLEX, and I'm not sure if some of the older solvers—but was the big innovation at the time was that the solver companies were starting to sort of make algorithms that were more generalizable?

Daniel Kirschen (00:32:04):

Yes, I think, I think so. It's one of my first PhD students in Manchester brought his own unit commitments using Lagrangian relaxation. And then just a few, two or three years later, suddenly you had those

Daniel Molzahn (00:32:22):

Integer programming

Daniel Kirschen (00:32:23):

Integer programming packages. And so on. And suddenly you realized we're wasting your time here.

Daniel Molzahn (00:32:30):

I mean, I've heard some folks like Dick O'Neill talk about kind of what was happening at the time in that space, and it seems like things were moving very, very rapidly. Right. In kind of the optimization community.

Daniel Kirschen (00:32:42):

Right. It would be interesting to talk to the French. Because the people at what was then EDF, they split into EDF and RTE, they had some top-notch optimization people who were doing their own things for unit commitment and OPF and then—

Daniel Molzahn (00:33:06):

Interesting. Yeah, we talked with Patrick last year, but we didn't get to talk about this topic. So maybe we, I was supposed to have dinner with Patrick tonight but unfortunately won't be able to join. So, but maybe we—that's a good follow up suggestion.

Daniel Kirschen (00:33:22):

Because they were quite influential.

Sairaj Dhople (00:33:25):

So Daniel, you referenced in those days the engineers were able to do it. Am I to take it that that also means that today the system has become a little bit more opaque, maybe more complex. Do you see that these types of technical solutions are more easy or less easy to try out today than it was back in the day?

Daniel Kirschen (00:33:47):

Oh, I think it's, we can do a lot more. Because you don't have to worry about the optimization engine and all the bugs in the optimization itself. You can just, work on formulating the problem. It doesn't mean that's trivial, but there's this clear division of labor between what is the optimization part and what is problem formulation part.

Sairaj Dhople (00:34:11):

What about the implementation piece of it? Do you find people, or let's say utilities, more willing to try new things today versus how it, back in the day?

Daniel Kirschen (00:34:21):

I haven't really worked closely with utilities' implementations, so I don't really know how to respond to how do they feel? I think the introduction of markets has made things a lot more—as we were saying earlier—optimization was frosting on the cake, but now it's no longer frosting. It's the cake itself. They have to, the market has to clear. They have some requirements. They're under pressure for doing better

and better, a better and better job. So they will work more closely with the vendors, develop better market clearing engines, better optimization engines. Does this answer your question?

Sairaj Dhople (00:35:14):

To some degree. I was hoping that you'd complete your sentence about introduction of markets has made things more.

Daniel Kirschen (00:35:25):

I think the introduction of market has put more pressure on the system operators to optimize things, and so to demand tools and to spend the resources to obtain those tools.

Julie Cohn (00:35:44):

And do you still, do you see big steps ahead to reach more improved optimized operations? Or is it now incremental changes?

Daniel Kirschen (00:36:02):

Well, there's a big discussion of whether we should have full opt, full AC optimization, rather than the linear optimization. I'm a bit skeptical.

Julie Cohn (00:36:13):

Can you explain that? For our non-technical listeners?

Daniel Kirschen (00:36:21):

Once you get into full AC optimization, the problems become very nonlinear and then you, solutions you get can be a lot less stable. And it's, from an operator's perspective, it's not just a question getting an optimal solution, it's a question getting a solution that's feasible. Mm-Hmm. Even though it might be mathematically feasible, if the solution goes from here to there, varies, instantly they don't like it. There is only so much, so many things they can do in a short amount of time.

Sairaj Dhople (00:37:01):

So Daniel, are there system operators around the world today that are using ACOPF?

Daniel Kirschen (00:37:10):

You mean to optimize the markets?

Sairaj Dhople (00:37:12):

Yes.

Daniel Kirschen (00:37:12):

Not to my knowledge. You have, you have this interesting division between the optimization that's done for the markets and then whatever optimization they may do for actual operation, which then introduces corrections of the market.

Sairaj Dhople (00:37:32):

And so what about the operations piece? Are there people solving ACOPF close to real time for operations?

Daniel Kirschen (00:37:39):

I don't know.

Julie Cohn (00:37:46):

As I understand it new technologies, inverter-based resources are both creating some new challenges and maybe new opportunities for competition, complication of how systems operate, and so forth. Are you interested, does your interest carry you into those other areas of investigation?

Daniel Kirschen (00:38:15):

A bit tangentially. What's going to be interesting there is that the number of active control, things you cannot change, is going to increase by orders of magnitude. The question is, can we still do central optimization or going to have to do decentralized optimization or how is that all going to work together?

Julie Cohn (00:38:36):

Do you have a perspective on that yet?

Daniel Kirschen (00:38:38):

No.

Julie Cohn (00:38:40):

Is that something you anticipate working on?

Daniel Kirschen (00:38:43):

Not really.

Julie Cohn (00:38:45):

Well, do you think the way you approached problems in the past, similar problems in the past, set a framework for people who are going to tackle it coming down the pike?

Daniel Kirschen (00:38:58):

Well, I think we make incremental improvements. We have now a better understanding of how systems work and how to—what solutions work, what solution doesn't really work, and then people work on that and build on that to come up with new ideas.

Julie Cohn (00:39:17):

I guess what I'm asking is, are, would you anticipate that everything that's been done up till now will be the framework that allows people to make the next step? Or do you think people will have to look critically at how we got to where we are today and say, we need a new way to do this?

Daniel Kirschen (00:39:45):

I would be amazed if there was a revolution rather than evolution. Because as we said, operators are mostly concerned with keeping the lights on, so they like things to not change too fast. And so if there's going to be a change, it's going to be progressive. Completely changing things from one day to the next, I don't see that. It's not in the DNA of the industry.

Julie Cohn (00:40:18):

Thank you.

Sairaj Dhople (00:40:20):

So keeping up with the timeline, Daniel, what brought you to Seattle?

Daniel Kirschen (00:40:26):

Oh, the University of Washington made me an offer I couldn't refuse. There was a combination of personal and professional things. Professional as I said, was a very nice offer at University Washington. Personally, it was 13 years ago, you start thinking about retirement and we couldn't imagine us retiring in the UK. So you decide. And you don't want to move just when you retire. So we decided this was a good time to do it. At the time there was also politics, in the sense that there was a new conservative government in the UK that was going toward political austerity, so that didn't look like it was going to be a good time for universities. And that turned out to be true. So there was a combination of factors. And then our son was also starting college in the US, so it was a way of not being too far from it.

Sairaj Dhople (00:41:29):

Has the environment here been very different from Manchester?

Daniel Kirschen (00:41:34):

It's more dynamic. You get better graduate students, a more intellectually challenging department.

Julie Cohn (00:41:47):

Something you said reminded me of a question we've asked some of our other interviewees, that has to do with sources of funding for research. I mean, you were with a company, CDC, that probably internally funded their research program. But when you were at the University of Manchester, was that funding coming from utilities, from government, from research organizations that wanted to see work done?

Daniel Kirschen (00:42:17):

So the funding was coming, it was a combination. There was a funding from the UK equivalent of NSF. There was funding from—some funding from industry utilities both in the UK and in France. There was some European Union funded projects.

Julie Cohn (00:42:34):

And did that influence your research questions at all? Who was paying for it?

Daniel Kirschen (00:42:40):

Absolutely. Absolutely. You have to, you have to find something that's going to be of interest to them and read what they're interested in, talk to them and try to get it to converge.

Julie Cohn (00:42:55):

And did that change when you came here?

Daniel Kirschen (00:43:01):

It's about the same general principle.

Sairaj Dhople (00:43:08):

Daniel, lots of highly cited papers. Any in particular that you would like to highlight? And if not, I would highlight one and ask you about it.

Daniel Kirschen (00:43:28):

No, not particularly. Which one are you thinking about?

Sairaj Dhople (00:43:30):

Well, I'm thinking about your paper, trying to do transmission allocation, power tracing, that line of work because we had Dr. Janusz [Bialek] and Mm-Hmm. <Affirmative> he referenced some of this work as well. It's a bit of an oddball effort. Like what sparked it and did you think that it would catch as much attention as it did? [*D. Kirschen and G. Strbac, "Tracing active and reactive power between generators and loads using real and imaginary currents," in IEEE Transactions on Power Systems, vol. 14, no. 4, pp. 1312-1319, Nov. 1999, doi: 10.1109/59.801890*]

Daniel Kirschen (00:43:55):

So how did that happen? I was always interested in those algorithms of, kind of topological algorithms. And then I was sitting in my desk in Manchester suddenly realizing we can actually do this. Started playing with it. And that's how, that's how it happened. Yeah, the number of citations for that is ridiculous compared to the practical importance of the whole thing.

Sairaj Dhople (00:44:32):

That's what I was trying to get at.

Daniel Kirschen (00:44:37):

Slightly embarrassing, I would say. Because some of those were, the directions that have been taken with that had some, some complete nonsense. You, you feel bad about how the paper and the ink wasted on some of the work that have been done with it.

Sairaj Dhople (00:44:54):

I think we all have examples of that, like papers that we really think should be propelled to the stratosphere versus the ones that we're like: How did that get as much attention as it did? So do you have a line of,

Daniel Kirschen (00:45:07):

Well, I thought it was a really interesting idea. I was thinking maybe there's something really useful that can come out of this. And I ended up—we ended up writing three papers on that line. And then after that we realized: this is not really going anywhere

Sairaj Dhople (00:45:25):

Except on Google Scholar.

Daniel Kirschen (00:45:26):

Except on Google Scholar.

Sairaj Dhople (00:45:31):

Was that idea ever used by anyone to either run the markets or figure out what was going on? I heard of some examples in New Zealand that tried this, but I don't know.

Daniel Kirschen (00:45:45):

Yeah, I remember vaguely some, some similar ideas that they had done in New Zealand that happened at about the same time. But I don't have any use. Recently some former PhD students of one of my colleagues had contacted me to see if they thought they could use it for something, had something like a reasonable idea, tracing carbon, carbon emissions, and things like that. The last paper I wrote on that topic I wrote—thought it's something you definitely don't want to put in the hand of an undergraduate student because it's totally counterintuitive.

Sairaj Dhople (00:46:32):

Can you say a little more?

Daniel Kirschen (00:46:35):

Some of the equations are actually—if you don't really understand what they mean, they give you the completely wrong idea of how a power system works.

Sairaj Dhople (00:46:43):

Interesting. so you referenced retirement, but I see no signs of you slowing down. I know you're now editor in chief of the new Transactions that we have on markets. Can you say a little bit more about that effort?

Daniel Kirschen (00:46:59):

So I just saw the announcement in Power Globe that they were looking for an editor in chief for these Transactions. I thought, oh, this is interesting. This is exactly the line of work. And I so asked some colleagues who were involved in that, should I apply and I applied, and I guess I was the best person to run the new journal.

Sairaj Dhople (00:47:21):

That seems to be made for you?

Daniel Kirschen (00:47:25):

I enjoyed the work and so it's—what's challenging about that is trying to make sure it remains relevant, that we publish papers that are really going to have an impact. We get a lot of papers, academic papers, that I look at them and say, this could be an interesting academic exercise, but it doesn't look like it's going to ever have practical applications. Now that's a dangerous thing to do because you could be, you could be completely wrong. You reject a paper that ends up changing the world. At the same time, we can't publish everything and we have to try to stick with things that, that, that are relevant.

Sairaj Dhople (00:48:16):

And I also reference your other recent project, your undergraduate textbook. Was there a reason why you embarked on that project?

Daniel Kirschen (00:48:27):

Well, I've been teaching undergraduate classes in power systems for a long time. I felt there was a need for a new textbook that was focusing on the more modern material, rather than some of what I like to describe as cobwebs. Getting rid of the cobwebs, focusing on what is important. Making it interesting for the students.

Julie Cohn (00:48:50):

Is it now published and out?

Daniel Kirschen (00:48:53):

It is published and out.

Julie Cohn (00:48:55):

And has it been widely adopted?

Daniel Kirschen (00:48:57):

I don't know yet.

Julie Cohn (00:49:00):

To be determined.

Daniel Kirschen (00:49:02):

Yeah. It just came out about two or four months ago.

Julie Cohn (00:49:04):

Oh, that recently?

Daniel Kirschen (00:49:06):

Yes. Yeah.

Julie Cohn (00:49:11):

What was your criteria for keeping something, a cobweb, in or excising it?

Daniel Kirschen (00:49:22):

Whether I like teaching it or not, I think that's understandable. If I find that something it's—if I enjoy teaching, it's probably good. I think it's important. Other people will find it—completely disagree with me.

Julie Cohn (00:49:48):

Dan, did you want to ask any further questions?

Daniel Molzahn (00:49:51):

Well, maybe a follow up on that is do you have some of the examples, I think I remember talking with you about one of the cobwebs at some point a couple years ago while you were writing this book with the transmission line parameter modeling, electromagnetics at some point. Were there other, like what examples of cobwebs? I don't know, maybe this is introducing controversy, but I'm just curious what your perspective is on what's a cobweb and what's not.

Daniel Kirschen (00:50:18):

That was the most obvious example of cobwebs. Solid, irrelevant. Other ones. Some of the existing textbooks will spend a lot of time with power flow solution methods that are totally irrelevant, that nobody uses anymore. With also things about how long can the transmission line be? What happens if you have a 900-mile transmission line when nobody's building a 900-mile transmission line anywhere these days? So why bother with that? Let's try to focus on things that I—

Daniel Molzahn (00:51:03):

I just say, then what did you then focus on more instead?

Daniel Kirschen (00:51:09):

Trying to help the student understand how a process actually works? What are the real issues? Trying to give them an intuitive understanding of how it works. And then once they have the intuitive understanding, let's do the math, and let's show that the math fits with the intuitive understanding.

Daniel Molzahn (00:51:32):

Got it. I see that. That's nice. I haven't checked out your book yet, but I will add it to my reading list.

Julie Cohn (00:51:38):

It's very interesting that you say it that way, because one of the topics that's come up in some of our interviews, and in some of my earlier research, had to do with the transition from using analog replications of power systems to digital representations of power systems. And the complaint was that a newly minted engineer would not have the opportunity to understand, at a kind of visceral level, how the power system worked, because they no longer interacted with say, a network analyzer. I'm assuming that by the 21st century, this point in the 21st century, the simulations to a large extent can recreate that experience. But I'm curious to know if you have a perspective on that.

Daniel Kirschen (00:52:31):

Well, I did play a little bit with analog simulators when I was a student, but that was really the very tail end of those, of those beautiful devices. I think it's not so much the tool that you are using, but the way you use it. If you just do a big numerical simulation with a thousand buses, getting an intuitive understanding for what happens, it's impossible. But you have to do a simulation of a small enough system that the human brain can figure it out and come up with some interesting examples of showing: if you tweak this thing either analog or digitally, you see this happens, that's what you try to do.

Julie Cohn (00:53:25):

Do you encourage your students or observe students choosing to physically build networks as well?

Daniel Kirschen (00:53:36):

No, I don't do hardware.

Julie Cohn (00:53:42):

Any follow up to that?

Sairaj Dhople (00:53:45):

Not really. I do want to take you all the way to the back. Why power and energy systems?

Daniel Kirschen (00:53:55):

It goes all the way back to my undergraduate days, where you had to choose, well, you had to choose an option, then you had to choose a final year project. Choosing options was really a personality of the faculty members. Power energy people seemed more interesting than the others. They were less old fashioned. In Belgium at the time, and I think it still is the case, you're an engineer first and you're an

electrical engineer. So you have a very broad—when you start, you can choose. I could have become a civil engineer, a chemical engineer. That was not interesting. Much more the electrical mechanical side. So that took me towards the electrical side. And then why power? Those blue capacitors for electronics look really cool.

Julie Cohn (00:54:58):

Jess, do you have a question?

Jess Slater (00:55:04):

Yes. kind of a two-part, but I'll start with the first one. You noted you liked explaining aspects of the market to electrical engineers. What are some of the gaps you've noticed in that knowledge that they have?

Daniel Kirschen (00:55:16):

Well, like economics doesn't necessarily come easily to engineers. The idea of balancing supply and demand and you need to explain that carefully for engineers to understand.

Jess Slater (00:55:30):

And do you think that academic curriculums can be modified to explain some of those things? Or should it be a completely separate process?

Daniel Kirschen (00:55:42):

Well, one thing I do in all my undergrad power system classes, even when we are not talking about markets, is to stress the fact that, if the money is not there, things are not going to happen. So you can spend a lot of time talking about technical parameters and things like that, but you have to keep reminding the students that there's an economic side and you have to look at the economics for it to happen. I like to draw distinctions between a system you might develop for the US Department of Defense, where money is no object, versus something in power systems where, if the money doesn't add up, it's not going to happen.

Jess Slater (00:56:23):

Okay. And then I wanted to ask another question. If you noted the challenges in publishing papers that are applicable, but that these academic exercises can still be beneficial, what advice would you offer to researchers and students to balance those two worlds?

Daniel Kirschen (00:56:42):

Work on important problems.

Jess Slater (00:56:44):

How would you—how could they—any advice in how to define what those important problems are?

Daniel Kirschen (00:56:52):

Think about the implications rather than: oh, there's this brilliant new theoretical approach of something, then I can come up with interesting research, academic research questions. Think about is this going to be, is this going to make a difference in the real world? Are there going to be applications for what I'm talking about?

Jess Slater (00:57:14):

Do you have an example with a student of walking them through that process?

Daniel Kirschen (00:57:24):

When I work with my graduate students it's kind of an iterative process. So they, it is not a clear thing where I tell—it will be more like they tell me something and I react positively or negatively or push them in one direction because I think: oh, this is interesting because this could have these applications.

Jess Slater (00:57:49):

Right. Thank you.

Daniel Kirschen (00:57:51):

I think I've been reasonably successful as an academic and I think it's because I had a bit this way of figuring out what could have an impact.

Julie Cohn (00:58:08):

That's actually a very nice segue to our usual closing question. Unless, Dan, do you have anything else you wanted to ask at this point?

Daniel Molzahn (00:58:17):

I think I've got a bunch of things I want to ask that I think, well, we're out time. But if I have the chance for one or two questions maybe circling back to some of the earlier discussion on the adoption of optimal power flow and what the operators have thought about it, what the market operators thought about it. Maybe one question: You were saying that market operators were getting a lot of pressure to sort of improve the—to improve—to use more optimization in their methodologies. Who is putting that pressure on them? Is that FERC? Is that the utility companies? Is like, is that some other stakeholder? Like what drives that?

Daniel Kirschen (00:58:58):

Well, if you are the system operator, you are, you have to respond to the market participants. And if the market participants are not happy with the way you're running the system, they're going to start asking you questions. Why did this happen? And I had a conversation with Kwok Cheung at Alstom GE, and he kept saying that they do get those questions. Why did the optimization engine come up with this solution? And then it's very hard question to answer for them. But this is the kind of questions they get, but it shows the type of pressure that they're getting, because for those market participants, it's real money. The vertically integrated utility didn't have to, didn't have this kind of pressure for real money. Right. The consumers

Daniel Molzahn (00:59:47):

Would, it does. So, it's the real money and it's explainability is, it sounds like those are the two kind-of key aspects of that?

Daniel Kirschen (00:59:55):

Yes, I think so. Well it's the real money leads to this, these questions.

Daniel Molzahn (01:00:03):

Got it. No, that, that makes sense. That's really interesting. Okay, maybe I'll go rapid fire through my other questions. And the, one of the other ones, you had talked about the difference between what the market operators were doing and clearing the markets, and what the actual system dispatch—how they

ran the system. Do you happen to know, does anyone, like, do people take advantage of that difference? Is there, it seems like if the markets are doing one thing and the system is actually doing something else, that there's a lot of smart folks out there and a lot of money on the table. Is there a way that people try to exploit those, those differences? I know that's somewhat speculative, but

Daniel Kirschen (01:00:44):

I don't know. That's a question that you would have to ask from a system operator: If people bid in a way that they figure out they will be asked to do something different than what they did in the market. I don't have the knowledge of that.

Daniel Molzahn (01:00:59):

Got it. Okay.

Daniel Kirschen (01:01:00):

It's possibility.

Daniel Molzahn (01:01:01):

I was curious. I thought maybe you'd be somebody who I would guess might know that answer, but—

Daniel Kirschen (01:01:08):

You overestimate my knowledge.

Daniel Molzahn (01:01:10):

Alright then. Then one other question, Julie, if I have another minute here. And one thing I found really interesting is you said the sort of LP-based methods would tend to give solutions that were more stable or that the operators kind of liked better in some sense. Do you know? Is there any way to try to quantify that or to bake that into the algorithm? Or do you have—is there an understanding of why those methods? If I'm interpreting what you said earlier, correctly.

Daniel Kirschen (01:01:48):

I think what I meant, and that's my understanding again, checking with people who actually are practitioners, is that the LP methods, if the LP gives you a solution, that's the solution by the mathematical definition. So there's no arguments. If the market will say, we are going to use this

algorithm, it's going to give you a solution. And that's the solution. And nobody can argue about it. If you have a nonlinear solver, well the solution can be here, can be there, and then you have to prove that this solution was actually the right one and not that one. And then you have, you open yourself to arguments.

Daniel Molzahn (01:02:26):

I see.

Daniel Kirschen (01:02:27):

So, the disaster in a market: if it, the market, doesn't clear, you get very unhappy people, you get lawsuits, and it's a complete disaster. So—

Daniel Molzahn (01:02:40):

So it again gets back to me this explainability guarantees performance method or like guarantees on the performance of the algorithm. It seems more important this context?

Daniel Kirschen (01:02:51):

Right. It may not be optimal, but if the rule says this is a solution, this is what you go for because the consequences of not having that are worse. You may not like it. But that's—those are the rules. You live by the rules.

Daniel Molzahn (01:03:07):

I see. I was thinking something along those lines, but that's really interesting. Julie, I apologize for—you said one question and I asked three. But I appreciate the time. I'll pass the baton back to you, Julie.

Julie Cohn (01:03:23):

Oh, if you—excuse me—did you have more or was that?

Daniel Molzahn (01:03:27):

No, no, that was it. Fine. I'm sure I could have a longer discussion about any one of those and many other things, but those were the three burning questions I had.

Julie Cohn (01:03:36):

Did you, did you have additional questions?

Sairaj Dhople (01:03:38):

I don't have any questions.

Jess Slater (01:03:40):

I do have one if it's okay. You noted that there's different problems being defined. Economists care about saving money, engineers care about keeping the lights on. How do you think the relationship between this focus on optimization of markets versus the optimization of operations can become more collaborative?

Daniel Kirschen (01:04:01):

Well, my next project is to actually write a third edition of this textbook on power system economics.

Jess Slater (01:04:07):

Oh, okay.

Daniel Kirschen (01:04:08):

So what I've been doing over the last few months is go back and read some of the more recent papers written by economists. And it's really, I found it really interesting that you have this body of papers from economists and this body of paper from engineers and they are, they don't overlap very much. And they look at the problem in a certain way, and we look at the problem in a different way. And what I'm going to try to do in this textbook is essentially try to—

Jess Slater (01:04:39):

Try to merge that.

Daniel Kirschen (01:04:40):

Try, try to merge that.

Jess Slater (01:04:41):

Very cool.

Julie Cohn (01:04:42):

Interesting.

Daniel Kirschen (01:04:46):

Because there are the journals where they like to publish and there are the journals where engineers publish.

Julie Cohn (01:04:51):

And they don't cite each other?

Daniel Kirschen (01:04:54):

Not enough. And one of the ambitions of these Transactions, which I'm editor in chief, is trying to be where they meet.

Julie Cohn (01:05:04):

Interesting.

Daniel Kirschen (01:05:05):

So far. We still get a lot more from the engineering side than from the economic side.

Jess Slater (01:05:10):

Who do you hope to be the audience of the book?

Daniel Kirschen (01:05:19):

I think it's going to be engineers. But I hope some economists might find it useful. I'm an engineer so they don't fully trust me. Just like I don't fully trust them.

Julie Cohn (01:05:36):

We've taken up more than an hour of your time, which we really appreciate. Sairaj, you have a question you usually close out with if you'd like.

Sairaj Dhople (01:05:46):

Yeah, absolutely. Daniel, this has been an absolute pleasure. So our closing question is maybe a very standard one that might be associated with a conversation like this, but do you have any words of advice for the future generation of power engineers?

Daniel Kirschen (01:06:19):

I think it's keeping the system in balance, or not just physical balance, but balance between the objectives, as we discussed. Having a clear idea what those objectives are, keeping the lights on, saving money, integrating renewables.

Julie Cohn (01:06:44):

Sounds like a good future to me. Well thank you so very much. Was there anything else you wanted to share with us before we go?

Daniel Kirschen (01:06:55):

No, this has been a pleasure.

Julie Cohn (01:06:58):

We, we've enjoyed it as well. And we really appreciate your time. Thank you.

[End of Interview]