

Algorithms & Power Systems Architecture:

Using Historical Analysis to Envision a Sustainable Future

Oral History Project

Interviewee: Fernando Alvarado

Interview Date: October 16, 2024 and November 20, 2024

Place: Online

Interviewer(s): Julie Cohn, Daniel Molzahn, Sairaj Dhople, Jess Slater

Transcriber: Temi

Keywords:

Fernando Alvarado, Frantisek Svojsik, Peru, Bill Tinney, Clarkson University, Computer Information and Control Engineering (CICE), University of Toledo, University of Wisconsin, congestion, networks, markets, economics, sparse matrix/matrices, Consortium for Electric Reliability Technology Solutions (CERTS), US Department of Energy, Electric Power Research Institute (EPRI), Christensen Associates (LRCA), California ISO, Bill Hogan, distributed generation, power flow, Jacobian matrix, Gauss-Seidel method, electromagnetic transients, Hydro-Quebec Research Institute (IREQ), Power World, parallel computing, resilience, Peter Sauer, Nathan Cohn, eigenvalue, MATLAB, Society for Industrial Applied Mathematics (SIAM), Iain Duff, Al Erisman, Thomas (Tom) Overbye, electromagnetic transients program (EMTP), Michael C. Ferris, Newton-Raphson method, voltage regulation, Sanford Klein, genetics, crossbreeding, cattle, Electric Power Research Institute (EPRI), microgrids.

Abstract:

The oral history interview with Dr. Fernando Alvarado took place over the course of two online meetings. In the first interview, Dr. Alvarado begins by describing his educational background and professional trajectory. From undergraduate work in Peru he moved to the United States to complete his advanced education at Clarkson University and eventually took a faculty position at the University of Wisconsin, Madison. Following retirement from his academic role, he worked for Christensen Associates (aka LCRA). When describing his work, he offers a three-legged stool analogy for the world – technology, economics, and politics. He explains his focus on software development, how to solve power flow problems, and later, application of these approaches to markets. He discusses solving power flow problems faster and in a way that scales. He argues that it is possible to control a power system with price signals, but this

may also introduce instability into the system. He reflects on industry's lack of interest in research as a result of how traditional utilities are compensated. He discusses optimization and the interaction between power system engineers and mathematicians to find better solutions. He laments the loss of collaboration across industry and academia following the end of modeling on analog physical simulators. He reflects on the development of sparse matrices and the use of parallel computing to solve very large problems. He considers how we would build a power system from scratch with all of today's knowledge and none of the legacy infrastructure and suggests we would embrace distributed generation and a focus on resiliency. He discusses his most cited paper, "Point of collapse and continuation methods for large AC/DC systems," published in 1993. He notes a voltage collapse in Seattle triggered interest in this work. He closes this part of the interview with advice to young power systems engineers to think outside the box.

In the second interview, Dr. Alvarado begins with reflection on whether his older code is still embedded in power systems software. He emphasizes the influence of the work of Bill Tinney on his own ideas and those of others in the industry. He continues discussion of the synergies between power systems people and mathematicians, noting that Tinney and Al Erismann collaborated. He describes how developments, such as application of sparse matrices to load flow problems, move from research to widespread commercial use. He talks about MATLAB, sparse matrices, sparse inverse, and the less pressing need for solutions with the advent of extremely fast computers. He further reflects on the transition from analog to digital computers and the application of different solutions to power flow, from Gauss-Seidel to Newton's method that became possible because of advances in sparse matrix methods. He then turns to markets and notes that the use of penalty factors to optimize systems under monopoly control was quite similar to the later efficiencies realized in markets. He laments that we do not, currently, take advantage of congestion conditions to consume power closer to the sources. He discusses negative prices. He discusses today's challenges with renewables, including the need for inertia, voltage regulation, and correct time constants. He describes collaboration on a genetics project, applying sparse matrices to cattle crossbreeding data. He discusses sources of research funding. He closes the second interview with a focus on microgrids, resiliency, and the need to reduce the impact of power interruptions as a national goal.

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:

[First Interview – October 16, 2024]

Julie Cohn ([00:00:02](#)):

This is Julie Cohn. I'm conducting an interview with Fernando Alvarado on October 16th, 2024, online. Daniel Molzahn will assist with the interview. Sairaj Dhople and Jess Slater are also participating in this interview and may ask questions. Dr. Alvarado, during today's interview, we are especially interested in your early work on power systems stability, optimization, and control, and how it later was carried forward into standardized practice—and of course, other reflections that you may choose to share. But first, we'd like to know a little bit more about you and your educational and professional background. So if you would, just take a moment to, to describe that for us.

Fernando Alvarado ([00:01:44](#)):

Okay. Well, I'll try to keep it short, but basically my father was an electrical engineer. I grew up in Lima, Peru, and I chose to attend, become an engineer as well. I love the field. As I tell people, I, you know, I love to solve problems. I mean, it's always fun to see things—. And I always saw my father was very passionate about it and took me in a couple of his jobs and everything. So I attended the university. I would say I did very well at the university and graduated in—at the time—just was still the Department of Electrical and Mechanical Engineering, but they already had branched out into electrical and mechanical. And our first computer, the IBM 1620, had just arrived while I was studying there. I and a couple of other friends that became—I could talk a lot about the—became kind of the gurus that knew how to run the computer.

Fernando Alvarado ([00:02:44](#)):

I mean, it was early on. So it was the mix. And I had the fortune of having two great professors from—not only from the university, but one of them specifically, I remember his name, Frantisek Svojsik, who was passionate about problem solving of power grids. Even though Peru's grid was not very big. I believe he was Swiss or German. Swiss. He was Swiss, and he was an adjunct professor at the university. He

worked for the utility. And my brother-in-law, who passed away, and I took to it. And in Peru, you had to do a thesis to graduate. And we chose the topic of solving power system problems. And we both knew that computers had just come. We had a brand-new computer, and we happened to run into a paper by a fellow by the name of Bill Tinney that had just published something on the topic.

Fernando Alvarado ([00:03:38](#)):

So my brother-in-law, and I came on two competing approaches to solve the problem. And that was our thesis. Then I graduated there, came to the US on a scholarship, actually a teaching assistantship for—it was a Fulbright assistantship. That's what it was. A Fulbright scholarship to Clarkson University, where I got my master's degree. Interestingly, not in power, in computer information—I'm sorry, in control, computers and control. Then after a year and a half, I wasn't ready to go back to Peru for a variety of personal and health reasons. Health was important. I ended up applying to a couple of universities. I have family in the US, you must know. My aunt—mother's sister, lived in Ohio. So I was kind of, she was my family and they recommended I apply to a few places.

Fernando Alvarado ([00:04:37](#)):

I applied to a number of places. Michigan was one of them. And they had this younger professor, Mark Enns, there, and they basically had some money to spend from Consumers Power, I think it was. So they offered me some assistantships to attend, and so I chose to go there, interestingly, in computer information and control engineering. My degree is technically in CICE, but my topic was power. So I attended, did my thesis on using computers for power system planning. A little primitive, a little naive, frankly, if I look at it now. And from there, before I graduated, they called me from the University of Toledo, because they were desperate. They were going to lose their accreditation, and they were desperate to get a young professor there so they would be accredited. So I started working before I graduated, first as a lecturer for about a semester.

Fernando Alvarado ([00:05:33](#)):

And as soon as I got my degree, I became an assistant professor. It was by happenstance. It was driving distance from Michigan, and my grant was running out, so it was a perfect match. I met my wife, we got married, we moved to Toledo, Ohio. And one day, out of the blue, they called me from Wisconsin saying: "excuse me, would you be interested in applying here?" I said, "maybe." So I told my wife, I said, "maybe we should go look at it." And she said, "no, I'm not interested, but you go." I went and I said, "I like this

program." So, bottom line, we love the position. I got hired as an assistant professor. That meant they did not have packages. Just a basic assistant professorship, but I loved the Big 10 environment, the real, high-power research university.

Fernando Alvarado ([00:06:25](#)):

You know, for the first time I felt like a small potato because I was traditionally used to being: "yeah, yeah, I do well." But it was a real challenge. And over the years, I helped hopefully build up a really reputable program at Wisconsin, that, to this day, continues. In fact, I'm very pleased to announce that it's probably stronger than ever at this point, really getting there. I'm very happy with what we accomplished, and I guess the rest is history. I retired way early—21 years ago. I can give you details in my career, but I published a lot on power systems. Then I became interested in, a little more in the economics of power systems and in congestion, in networks, and in markets. And I finally realized that markets, in fact, when I serve in the—probably I'm talking too much—

Fernando Alvarado ([00:07:19](#)):

When I served in the IEEE-USA Energy Policy Committee, I basically have this stool analogy of what the world looks like. You need technology, that's one leg. You need economics, and that's the other leg. You need to understand that just because it's a good idea, it's not going to be funded. And the third is, you need the politics. You need the policy people to agree that this is a good idea. So, I became a lot more beyond just power. I became very interested in solar and renewables. And at that point, I retired, and I've had a complete career after that in working on a zillion other things, but not publishing as much. I'm not into research as much as helping people. And you know, just working in the—I'm still developing some software now and then, and occasionally I go back to the sparse matrix ideas. But anyway I can make it a lot longer, but when I stop there, are you still there?

Julie Cohn ([00:08:19](#)):

Yes. I just had to restart the microphone. So you really straddled both the academic world and then eventually, it sounds like, an entrepreneurial world in power or electrification. Is that a good way to describe it?

Fernando Alvarado ([00:08:40](#)):

That's more or less accurate? I decided—I did the research part and then a little bit of the—. The answer is yes.

Julie Cohn ([00:08:51](#)):

And was your research, oh, I'm sorry. Go ahead.

Fernando Alvarado ([00:08:54](#)):

No, no, go ahead.

Julie Cohn ([00:08:55](#)):

Was your research theoretically focused or more focused toward applicable approaches that could be adopted by industry after you had solved a research problem?

Fernando Alvarado ([00:09:10](#)):

Well, that's a very good question. In the early days, we were just trying to solve the traditional power flow program better, problem better, you know. A very basic set of ideas, solving things faster. Computers were not that fast. And I was part of the group that came to a very good understanding of how to produce great software for power system analysis. And I even, I bet in today's code, some of the code out there, you probably will still find deep, deep in there some lines of code I wrote back then. I know that for a fact at least one program that is out there. And, but eventually I realized that a lot of the things that had already been done by us and by others, in mathematics and everything, were becoming like a commodity.

Fernando Alvarado ([00:10:06](#)):

And my revelation was one time that I got invited to give a lecture at a not-to-be-named a company in upper New York that was in the software area. And I gave my best shot. I got all my best ideas, said, “this is why you need to do this, this, and that.” They paid me well and said goodbye. And I never heard from them again. And I said, “Hmm, maybe this is not what I need to be doing.” So, I gave a lot of my ideas very cheaply, and you know, it's not resentful. It's just learning about how things work. And I, that's when I became interested in a little more “entrepreneurship.” And then when the opportunity arose to help people, when the financial people were arriving to the realization that power market, power systems were going to be a very important part of the financial future of the country, they needed some people

that understood systems. The people they had working on them had no clue how our power system worked, or the constraints, or the networks, or anything. They just—like—you put a price for energy and people will put it there. And I said, "oh, it doesn't work that way. You put it here. You can't take it out there. You know, it just doesn't work that way." And so, I became very interested in helping those, and that's what eventually led to my retirement and my new career direction.

Julie Cohn ([00:11:33](#)):

So did you retain relationships between your academic world and the world that was looking for your assistance in software development and applicable computation in developing market designs, that sort of thing?

Fernando Alvarado ([00:11:50](#)):

Yeah. We actually did have a group. Daniel's probably familiar with a lot of them. CERTS. The government funded an effort of essentially incorporating reliability into the grid and funded a lot of things. That's what funded a lot of my research in later years, that integrated economics, and integrated power grids, congestion, and all that. And the connection was through some grants and Department of Energy work. To that extent, even to this day, I still retain contact with some of the people, most of them now retired. I've also retained my association with at least one of the key conferences in the field. But I can say that's the, really, the best, most fun, and academic conference in the world. And that's PSCC. Most of the other conferences that I participated in became, if you pardon the word, were too commercial.

Fernando Alvarado ([00:12:50](#)):

They were no longer interested in the research and in the innovation, they were interested in selling products. I remember that back in the '80s, all of a sudden it was not who had the better idea, but whose vendor had the better shrimp in their suite, and were you going to get invited? I mean, at that point, I realized, wait, this has changed. We're not judging people by the quality of their work and the papers and originality. We're now seeing who can sell more. So I, at that point, I tried to branch a little more—I'm not saying anything wrong with becoming commercial, but it's just that it's a different tack.

Julie Cohn ([00:13:27](#)):

This, this is jumping ahead in our sequence, but, when you witnessed that shift, did it affect the quality of the service provided by the utilities, by the power industry?

Fernando Alvarado ([00:13:47](#)):

That's a good question. That's actually a very good question that I need to answer somewhat carefully. The reason is because the utilities, as I saw them, at all times, were never really interested in our research directly. Indirectly they were. But they were interested in the product of our research through essentially better software they were buying from vendors and everything. But they never directly, at least in my case—I know they did it for some other institutions, directly funded me to do original work in large-scale computation. It was done—a couple of EPRI projects, yes, they did fund, but they were specialized in a slightly different direction. The main thing that the power industry wanted is bodies and students trained in the area. And of course, at a research university like Wisconsin, that was not necessarily our main product. Our main product was students, yes, but research, yes. So we never saw eye to eye with the regular utilities. Not that they were antagonistic in any way, but they were not big supporters. The bigger supporters were the vendors, but the vendors became competitors with each other. And, as I mentioned earlier, it created a little bit of a conflict. And so in terms of utilities, they were the beneficiaries of a lot of this research, but they were not necessarily the early supporters of the research in an active way.

Fernando Alvarado ([00:15:23](#)):

Sorry.

Julie Cohn ([00:15:24](#)):

And just to take this one more step further. So, the competition between the vendors, was that facilitated by the solution of some of the problems that you had been working on?

Fernando Alvarado ([00:15:39](#)):

Oh, yeah. The problems that we were solving—for example, the idea that you could solve very large networks and from there derive the prices. From there, you could actually find limits of transfer capability. You could find contingency-constrained optimization. That was a big one. It still is today, to this day. That's how markets clear. Markets clear based on a contingency-constraint optimization of the system. That's how market's clear. And those became feasible. And different vendors produced it. And utilities, and now the ISOs, all have to have the best product they can. And really, we're still constrained

in what markets can do by the computational capability of what can be calculated in realistic time to clear a market. So there's still a need for that.

Fernando Alvarado ([00:16:38](#)):

But in terms of the fundamental research needed to get us to that capability, I think at this point, I wouldn't say everything that can be invented has been invented, but you know, it's basically incremental and not at the level it was when we were first discovering: Hey, if you do it this way, it's going to be much faster, or get better results or be more robust or something. Or sometimes asking the right question, too. For example, because the grid is divided into regions that don't always talk to each other, you have the situation that at one point it became very important to try to find out what's going on in somebody else's system, because it's affecting you, and you have no way of knowing. So we worked on techniques to try to detect, for example, an unreported line out in somebody else's system, which is something I came up with. And I said, you can do it. You just can't do it from one snapshot. You need two or three snapshots. And then by observing how they move, you can see: hey, that line is out. And then you can act on it because it would have a big difference for what you're going to do in your system. That of course has been now changed, because it's a lot more integrated.

Julie Cohn ([00:17:52](#)):

Okay. Circling back, once you had left academia, were you ever associated with other existing companies or were you consulting and developing work on your own or through the companies that you founded?

Fernando Alvarado ([00:18:10](#)):

I went to work immediately directly for an economics company with a group of three. There were two engineers and one economist in a little power system subgroup of, essentially the company was Christensen Associates here in town, some friends that had some contact in the utility. And we did a couple of projects for them helping people understand power networks and everything. And then a big client came along and said: "we want help with electric markets." So that's how I got involved with the big company through Christensen Associates. And we negotiated a good arrangement that has been very good for me and in which we helped them. But we put things on the line. I mean, I said, "if you don't do better than the competitors, you don't have to pay us, basically, but if you do, we'll send you the bill." And that was the arrangement.

Julie Cohn ([00:19:03](#)):

Great. Okay. Well, so looking back, you've obviously had multiple roles in the industry and dealt with a really wide range of topics, technical topics, over your academic and professional career. So I'm curious, if you were to highlight two or three of either the thorniest or most compelling technical challenges you addressed, which would they be?

Fernando Alvarado ([00:19:34](#)):

This is going to be very strange. Very, very strange. I can probably name three things. One is very conventional. The other one is something that is more incremental. And the other one is something that nobody knows about and nobody cares. And I do. The first one was the realization that it wasn't just a matter of solving the power flow problem, but essentially the information you give out from those so-called Jacobians was very rich and allowed you to compute the famous penalty factors, which essentially told you how efficiently the system was running. And that was something that I think I've been somewhat recognized. Another one that I think I've been recognized for, and I think I contributed, was the understanding that it's not about solving faster, but it's also solving a problem faster in a way that it scales.

Fernando Alvarado ([00:20:39](#)):

If you double the size of the problem, you are not all of a sudden talking about four times or eight times the effort. It's more or less linear, not quite linear. And the understanding of that, that with sparse matrix techniques, you can control how—you can solve bigger and bigger problems without the computation getting out of hand. That was another kind of contribution I think I made to the basic fundamentals of the industry. And the other one was the one nobody cares about or even knows about. But if I told you that I came up with a technique where, basically, as the system grows in time, in size, the time to take to compute things grows less than linearly with system size. Nobody understands why. I mean, I'm the only one that cares about that.

Fernando Alvarado ([00:21:35](#)):

Something that all of a sudden, if you have enough parallel computers, you can solve a problem faster. And you know, relatively faster, as it grows, rather than slower. It is not even a linear growth. It's logarithmic growth. It's published in a Russian mathematical paper. To me, that was a contribution that,

one of those "aha" moments that I know, I know nobody before me knew that, that I know of. But of course, it's very obscure and no power engineer really cares. And there's, you know, it's all going to be replaced with one computing anyway. But it was, in some cases, the contributions are somewhat obscure. Another minor one is the realization, in the early days of computation, when we were all working on sparse matrices, we wanted the problem to be faster, but by realizing that the ordering of the equations mattered, but you don't always want to reduce computation, sometimes you want to make it a little more parallel. And that was also efficiency contribution, original work in my part, at least that--maybe it's not appreciated, but I appreciate it.

Julie Cohn ([00:22:50](#)):

I'm going to imagine that having mentioned those, not just three, but four really significant contributions, that either Dan or Sairaj will be ready to jump in with a follow-on question or two,

Fernando Alvarado ([00:23:04](#)):

Maybe. I don't know. As I said, I don't even—I may not even have copies of some of those anymore. But those are the early days—I mean, in later days, it's been more about the understanding of market. Oh yeah, no, one more. This is probably my most important relevance today. Sorry. And that is the understanding that, let's see, you can, in fact, control a power system from price, with price signals alone. You can. And this was actually said by a fellow, by Fred Schweppe, years and years ago. And Dan Molzahn knows about him. However, when I discovered this, if you're not careful, you can make the system more efficient but unstable. So I published something on the stability, the instability that you can create into the system, if your feedback system of prices to actual actuators in the system is not designed correctly, you can end up with a system that becomes unstable because of the market. That to me, is probably my most important contribution, actually.

Daniel Molzahn ([00:24:21](#)):

So, Fernando, I think I could expand on each of these points. And I think you're also not the only one that cares about them. I could say there's at least two people that care about all these pieces. Because those are super interesting. And I suspect a lot of other folks at Wisconsin cared as well, if nowhere else. So on the last point, on looking at price signals and feedback price signals in the system. So how did people—was this a surprise to them? How was that communicated, and how did people react when you were talking with them about that?

Fernando Alvarado ([00:24:55](#)):

It's still being cited and people are still looking it up. And I get questions once in a while, but I don't think people really care or understand that much, the fact that there's a coupling between system stability and markets. People think of them as separate. I can, for example, tell you that part of the big meltdown, brouhaha, years and years ago, from Enron in California was really a bad market design that resulted in this instability. It's in a different timescale. But if you couple real actuators on power system operations to market signals, you can produce incentives that can destabilize or create problems in the system. And some people, every time I talked to—at least when I went to California ISO years and years ago, and I was telling them, “You cannot separate the real-time market and pretend it's separate from the day-ahead market.” “Oh, no, no, they're separate markets. Oh, no, no, no, no. In realtime, we do what we need to do.” And I said, “no, you can't do that. You're going to get in trouble.” Guess what? They got in trouble. Did I get any acknowledgement? No. You know, it's just, I knew it. I told them. Ignored.

Daniel Molzahn ([00:26:20](#)):

And was that a common—We've talked with quite a few folks that have been involved in the markets, developments of markets. I actually have other questions for you going back earlier than this markets era. But, in this space for a second—it seemed like that was a pretty common theme that we've been hearing from a lot of our interviewees, was the effort it took to try to educate the economists and the policymakers. And so, can you tell us a little bit more about what that process was like? It sounds like this was not unique to you, from what we've heard elsewhere.

Fernando Alvarado ([00:27:02](#)):

No, and I'll tell you what the future problem is, for people who are not listening. I'll tell that before this interview is over, to me, is my most important, compelling thing to do in the future. I'll come back to that. But it's basically the fact that there was one economist, Ho—the Harvard guy. <Bill Hogan>

Daniel Molzahn ([00:27:25](#)):

Bill Hogan.

Fernando Alvarado ([00:27:26](#)):

Bill Hogan, yeah. Not Ho. Bill Hogan. He understood it. He understood markets. He didn't understand market dynamics. He didn't understand any of them—unit commitments, things like that. But he did understand markets and congestion, of what it does to power systems. So he thought that's all he needed to understand. And they created these markets based on that, and that's fine. It was much better than what some other famous MIT persons used to say is: "well, you know, in a power system, the prices are random." They are not; they follow very specific patterns. And understanding of that—now, people understand it. And this is why markets are much more efficient today. But they still don't take the intertemporal effects and things like that into consideration.

Daniel Molzahn ([00:28:13](#)):

I had one other question on the market side, on a different aspect. So, you had mentioned the industry being most interested in the students that you're producing, and the research was, you know, nice to have, but maybe not their direct interest. Some of the folks that we had interviewed before had also mentioned this—telling similar anecdotes—and they had often attributed a lot of that to the development of markets. That it used to be that the industry was much more interested in research and then markets came along and everyone had to deregulate and was worried about competition, and therefore they cut their research budgets. And then, at that point, it was kind of a step change. But from what you described earlier, that doesn't seem to be your experience with that.

Fernando Alvarado ([00:29:08](#)):

No, mine is very different. My experience is very different. Utilities are monopolies, they're regulated monopolies. There's supposedly a reason, and I'm going to go back to that because that's my pet peeve today. If I leave any legacy, it's going to be the fact that utilities don't have to be monopolies anymore. That's my new message to the world. But, and I'll explain why, but the reason—they are monopolies, so they are not interested in research. I'll quote one of the people that worked for a local utility that was in charge of the research budget for this whole thing, and, years back, and basically his attitude was: "why should we spend our money on research?" And I, at the time, I didn't connect the fact that it wasn't their money. They're a regulated utility, they're going to make money no matter what, no matter what they do, no matter how bad they are. It is money that they're investing on behalf of their customers that they should have been looking at. By investing in these new ideas, we now serve our customers better. But that's never been the thinking, not even today of utilities.

Daniel Molzahn ([00:30:25](#)):

Got it. Interesting. Yeah, that's an interesting explanation. And it's a little bit different than things we'd heard before, but I think some of the folks we were talking with before had come of age more in the markets era, and so it was seen as: "oh, this is a problem with markets." But maybe that was not necessarily the case.

Fernando Alvarado ([00:30:44](#)):

No, I don't think it's markets alone. Markets may have brought up to the fore some of it. But I don't know if it's time for me to expound on the other idea. We have time, but at some point, let me elaborate on distributed generation, because it has a national security implication, and that is what I intend to do with the rest of my days. Okay.

Daniel Molzahn ([00:31:07](#)):

Got it. I don't know, Julie, if—I have questions about some of the other points that you had raised. I'm happy to switch gears if—.

Fernando Alvarado ([00:31:15](#)):

Let's answer your questions. As long as I have a little chance to get back to that point.

Julie Cohn ([00:31:20](#)):

We'll set aside time to look ahead.

Fernando Alvarado ([00:31:23](#)):

I want a little time, yeah, the last five minutes to look ahead at what I think needs to be done and needs to be done desperately. Okay.

Julie Cohn ([00:31:32](#)):

Great.

Daniel Molzahn ([00:31:33](#)):

So, Julie, if you don't mind, I'm sure Sairaj, you have questions as well, but I'm just very interested in these topics and I want to make sure I can ask a couple more questions. I think your first point that you had mentioned, this realization that it was more than just solving power flow, that you could extract a lot of other information from the solution to the power flow problem, or the Jacobians, and this sort of thing. Now it seems like that's very well understood—I mean, I took classes from folks at Wisconsin who—some of the papers that you worked on—we would teach this in our classes, right? But was it well known or suspected at the time, and you formalized it? Or was that a fundamentally new concept?

Fernando Alvarado ([00:32:32](#)):

I think I basically formalized the ability to compute those things efficiently, rather than the new idea. People knew about these, for example, the penalty factors, and they had improved their ways of computing them. My method for computing the penalty factors was so superior, but in a way, I hate to say it, but in retrospect, it should have been obvious. And maybe it was to some people, but it had never been openly presented that way. And it's more, maybe I didn't invent it, but I probably discovered it, stumbled upon the idea, you know, explicitly. I made it explicit. Because those numbers were there all along. It's essentially—anybody in optimization that knew about Lagrange multipliers, probably knew about it, but it had never been put in the context of power systems.

Daniel Molzahn ([00:33:24](#)):

So, was there—I mean, that's an interesting observation. Was there an intersection between the operations research/optimization community and the power community at the time?

Fernando Alvarado ([00:33:36](#)):

Very interesting, very historical question in the sense that, right at the time that the early days of this thing was were happening, there were some mathematicians that were also beginning to look at this. And again, the original paper on this, according to power engineers, according to engineers, is Bill Tinney. He invented sparse matrices as well. He did. But there was, in the mathematical community, there was Erisman, there were a couple of others that invented sparse matrices. So who wins? And there is Parker. My feeling is the real inventor is the one, not only that had the idea, but applied it to a practical problem. And that's Bill Tinney. But there was a lot of interaction—even to this day—between operations research people and optimization people in mathematics.

Fernando Alvarado ([00:34:30](#)):

And the power engineering community. I interacted a lot with the computer science department and also with the mathematics department. One of my favorite things was to attend mathematician's conferences in Europe. By the way, unlike the US, they're really, really well funded, because Europe devotes a lot of funding to just esoteric things that don't necessarily yield tomorrow's better whatever. Now, good or bad, some people say the US model is better. I don't disagree entirely. But it's certainly good as a researcher to be pampered for just some mathematical ideas.

Daniel Molzahn ([00:35:13](#)):

Yeah, I've had the opportunity to work with some very good European mathematicians, so I've been fortunate in that sense as well.

Fernando Alvarado ([00:35:21](#)):

Exactly. You know what I mean, then?

Daniel Molzahn ([00:35:24](#)):

Yeah, I do. So, I guess when we're looking at sparsity-exploiting methods, and you said, your own story going back, and we're fortunate to have come across the first very early papers in these—one of Bill Tinney's early papers—you re-implemented it yourself and demonstrated as part of your undergraduate thesis. Was it well recognized at the time that this was the obvious thing to do? Or was there—there was many competing alternatives—that this was the one that—

Fernando Alvarado ([00:35:57](#)):

No. When I got back to Wisconsin, after I was in Toledo and everything, people were still promoting Gauss-Seidel methods that—were still talking about: "oh, we don't need all this." And, yeah, it took some convincing to finally demonstrate: "oh yeah, sometimes Newton's method doesn't converge," or "Why would you want to use that when this is—" You know, there were a lot of—. And in the end, like all things, it's like the electric car, eventually just nobody is going to be: "why did the people even question it?" But it's the same kind of thinking. People were set in their ways. The one thing that disappeared instantly, instantly, was the hardware simulator. Within two years, once people were able to solve it—even with crude techniques—the more minimal power flow problem—the simulators - poof -

disappeared. They weren't needed anymore. And then a lot of—that was actually the bad, bad thing, historical bad thing of that having happened is, when there were physical simulators, like the one we had in the lab, Wisconsin, across from my office, when I first arrived, there was still a simulator that nobody was using.

Fernando Alvarado ([00:37:08](#)):

And that brought together a lot of engineers from utilities, from the university, in one room over summers to study next year's system with a lot of interaction. The interactions, once you put a computer on somebody's desk, they don't have to talk to anybody. This is before the internet, so they don't even interact like we're interacting now. You know, it was just like everybody on their own. We don't need, we don't need to talk.

Julie Cohn ([00:37:34](#)):

Before you carry on. Dan, I just want to clarify. So when you talk about a hardware simulator, was that the Network Analyzer?

Fernando Alvarado ([00:37:41](#)):

Yeah, yeah. Network Analyzer. That's exactly what I'm talking about.

Julie Cohn ([00:37:44](#)):

Okay. And then this tension between the Gauss-Seidel approach and the sparse matrix approach, where was that negotiated? Was that just, like, in conversations you had in the hall with a colleague, or was it at conferences, or were there competing papers in the publications? How did that unfold?

Fernando Alvarado ([00:38:03](#)):

I think gradually in publications and papers, conversations. But anybody that knew about the power of solving large-scale problems realized that the iterative, Gauss-Seidel method was doomed. But yeah, it took some time because there were some very good people that had originally promoted it. The famous El-Abiad you know, Ahmed El-Abiad, who really—I mean, once you come up with a great idea, you're reluctant to accept that a better idea has come along, you know?

Julie Cohn ([00:38:36](#)):

So, and just to get a sense of the timeframe, so the Tinney paper was published in the late 1960s, is that right? Am I remembering?

Fernando Alvarado ([00:38:46](#)):

Yes. But there was an original predecessor in '63, I believe, that began planting the seed by—oh, I forgot the name. I can probably find it. But the original paper was '67 or something. I can probably find it.

Julie Cohn ([00:39:02](#)):

Okay.

Fernando Alvarado ([00:39:02](#)):

Because it was just at the time I was working on my thesis and I was working on Gauss-Seidel and my brother-in-law said, "Hey, this is new paper, when don't we try it?" And we both worked—and we divided the work. I chose Gauss-Seidel because it was easier. He chose the other one. And we both came up with it. And I, at that point, I realized he's got the better method.

Julie Cohn ([00:39:23](#)):

And then my understanding is that people started abandoning—that the analog machines were pretty much abandoned by the mid to late '80s. There were like one or two left by the late '80s, and then that was it.

Fernando Alvarado ([00:39:38](#)):

Well, you've got to be careful, because, for the purpose of power flow and network analysis in steady state, the machines were abandoned early on.

Julie Cohn ([00:39:50](#)):

Okay.

Fernando Alvarado ([00:39:50](#)):

But to analyze—my other pet project I worked on a lot was the electromagnetic transients. Fast transients. And those were much harder to tackle with numerical methods and machines. Because you

needed so much more computing power. Instead of working with phasors that you basically are working on a one-second interval and long-term, steady state. When you're analyzing transients, you're dealing with a lot more computations in time, and you need a lot more accuracy. And for those purposes, the simulators, physical simulators, lived well into the '80s. One of the best ones was at IREQ in Quebec. And Manitoba had another great one, and a lot of the Canadian places, but a lot of the US labs probably did have them, but those went into the '80s and maybe even the '90s.

Julie Cohn ([00:40:44](#)):

Okay. Thank you. Okay. Sorry, Dan, did you want to carry on?

Daniel Molzahn ([00:40:48](#)):

Well, yeah, maybe to build off that question. Some of the feedback, or the thoughts that we had from other interviewees, were that this transition from having physical simulators, analog computers and this sort of thing, to digital computing was a loss in a different way, in the sense that you had less intuition about the real system.

Fernando Alvarado ([00:41:15](#)):

Yeah.

Daniel Molzahn ([00:41:15](#)):

And, you didn't have, you couldn't feel it. Right. And so, I'm curious, I was expecting you to say something along those lines when you said, "not getting people together." Was that an issue in your mind?

Fernando Alvarado ([00:41:30](#)):

No, no. I should have mentioned that. The loss of intuition. The fact that, you know, when you look at the number: one looks as much as 1,000. It's just no difference. But, on the other hand, when you have something and there's a different, <gestures to demonstrate point> one is going to be a flow, 1,000 is going to blow up a fuse. I mean, the intuition of: you move this wiggle here and you're instantly seeing the—so there is a lot, no, I should have mentioned it. I should have said the loss of intuition and calibration that comes from having an analog is lost when you do only digital. But let me add something. And that is, this is why some of the graphics things came back, and Power World was very successful.

Not because they had the better software behind it. It's because they had the better visualization. They allowed for the pictures, feedback. Humans like to react to—visually, rather than numbers on a page. So that was regained somewhat in the later years of the transition to computation.

Daniel Molzahn ([00:42:35](#)):

Do you think it's—now of course we have visualizations, and digital computing has taken over the world, right? But do you think we have still lost something? Like are today's students missing something that you would've learned, say, during your education?

Fernando Alvarado ([00:42:52](#)):

Well, I'm going to say something that is probably not going to sit well in any American university, but, in Peru—and I'm not saying Peru is better—but in one way, we did have to take one course on being an electrician. How to wire a switch, how to connect things physically, how to do that. Because, you say you're an electrical engineer and everybody expects you to know what a switch is, and you know, it's something that somehow you cannot gain from equations, from a paper, or from a computer. Sometimes you've got to deal with the physical world in some tiny way. And some of our labs do that. I'm not saying they don't. But in retrospect, I think that is a very important part of an education of an engineer. We want to have an engineer, not a mathematician. You need to realize that you're dealing with the physical world, not just numbers.

Daniel Molzahn ([00:43:56](#)):

That's interesting. And I think, during, I spent some time at utility companies, and this was always the first thing they would do with us as interns. For instance, is, out in the field: here's a transformer. So, going back through your list of compelling technical challenges, one other one that you mentioned was the ability to use parallel computing to make scalability, log-scaling in terms of system size. Was that—today, everything is parallelized, right? We have how many cores come on a chip nowadays, right? But was that understood at the time? That that was the direction? Because computers were also getting faster, right? Was there a need to do parallelization?

Fernando Alvarado ([00:44:47](#)):

Yeah. And the thing is, there's two kinds of parallelization then. One is explicit, the other is implicit. By having, for example—to put it in very basic terms, <gestures to illustrate explanation> in different matrix

ordering, that doesn't emphasize reducing the computations to a minimum, but rather, spreading them out—even though you end up with more computations. In other words, the elimination tree, if you're familiar with the notion, instead of having computations along the path, you now distribute them. So it's not a [*skinny*] tree anymore, it's got many branches. You end up computing more, but you can solve it faster. Now, if you design an ordering of a matrix that is designed to have a little broader tree, it is naturally, if you put it on a parallel computer, going to work faster, even though it's crunching a lot more numbers, because you naturally have given it a problem that is more parallel, inherently, the way you formulated it.

Fernando Alvarado ([00:45:47](#)):

So one thing is implicit parallelization, which is benefited from thinking about: the holy grail is not to minimize computations, but it's to minimize solution time with equipment you have. That's the implicit. The explicit is when you now partition the program, delegate this to this computer, delegate, for example—A classic example is, for example, would be contingency analysis. If you're going to contingency analysis, you can tell a thousand contingencies, you have a thousand computers. Each computer analyzes one of them, bam, come back and tell me the results. That is explicit. But the implicit is within a single problem. How you formulate it can affect how fast it solves in a serial computer. And in a computer that has some parallel capabilities. You've got to consider there's a trade-off between the two. And that's kind of what I worked on for some time and understanding that part of the equation. Now, with sufficiently fast computers, none of this matters. I mean, they're all fast enough.

Daniel Molzahn ([00:46:51](#)):

So one other follow-up on this, because I thought the way you described it was interesting. So I mean, there's these connections, right, to graph theoretic notions, right? You describe it as a tree. And was that known at the time? So going back to when Tinney was first developing these things, was it—the graph connection was obvious, or that was—

Fernando Alvarado ([00:47:14](#)):

It was. But the connection on the implications on the shape of the trees, and the tree structures and all that, that was part of the early research. Those are some of the things that actually—I worked with Tinney himself, actually. We had, to me, the best publication that actually mattered was a chapter in a book that was created, I don't even know where it is, but where we actually explained everything about

all of these things that we learned in 10 to 15 years of sparse matrices. And the realization that: it's not all about minimizing total computations was very big. And in the little handout that I just gave you of all my ideas, that you can follow up on later, I do have mentions of some of those things, the way I think they evolved.

Daniel Molzahn ([00:47:57](#)):

Great. This has been really interesting, and from my point of view just really insightful just to see what the thought process was at the time and how these were being developed. Really appreciate the—I have many more questions I could ask, but I feel like I should maybe pass it back to Julie and Sairaj if there's other questions that we should get to first.

Julie Cohn ([00:48:20](#)):

Sairaj, did you want to jump in at this moment?

Sairaj Dhople ([00:48:23](#)):

Sure. I want to touch upon something that you mentioned, Fernando, concepts or algorithms that were obvious at the time, but no one really took them on, and then suddenly they became the vogue, right? I wonder if, from your vantage point today, you can offer some comments on similar methods or algorithms that you see should be obvious, but there is hesitancy to adopt them. And maybe looking into your crystal ball into the future, they are going to be industry standards and academic standards going forward. Can you think of any examples of that type?

Fernando Alvarado ([00:49:00](#)):

If you broaden the definition to beyond just algorithms, concepts for operating a power system, then the answer is very much "yes." If you want me to talk about algorithms, no, I can't see anything obvious. But in terms of how a system can and should work, I see a very, very, very obvious, and this is getting on my soapbox for the future that I see. And I ask myself the following question: And this is something that, that essentially pervades a lot of very, very basic ideas. And that is: imagine that we went to a place that we had no power system at all. Nothing at all. But we had all the knowledge of what we have today: about solar, about nuclear, about fossil fuels, about climate change, about transportation, about everything we know, mathematics, computers, and everything. Would we have the same system?

Fernando Alvarado ([00:50:03](#)):

And my answer is "no." And my answer is, we would start it very differently. We would not probably start with utilities. We probably would have started with everybody buying their own little solar cell, like they do in some places in India, buying a small battery, and running their own little transistor radio, whatever it is, off it, and then beginning it. But it would not have been done from a centrally planned standpoint as it is now, with the necessity to have this monopoly. Now, I'm not arguing that we don't need interconnections, but they would've evolved very differently. And this is what's needed. And right now, the thing that we're missing, the fundamental thing that is missing in power systems, and in the country at large, is the concept of resilience. Not as defined by the utility, but as defined by the end user. And I'll tell you specifically what I'm talking about.

Fernando Alvarado ([00:51:00](#)):

When you mention the word "resilience," utilities simply want more money to make their system more resilient to failures through hurricanes and everything else. That is their thinking: "oh, give us more money, trillions and trillions and we'll—" and they'll never be able to get to that level. When I think of what resilience is, I have a friend in Florida that has 54 solar panels and no battery. And I'm thinking, are you crazy? You know, the hurricane came and he was without power for three days. And I'm telling him, "Really, you know, just get yourself a car or battery and you have your problem solved." And if everybody began thinking about that way, building it from the ground up instead of top down, we would end up with a much—this is my soapbox now. Okay. So the answer would be then, oh, can we be independent?

Fernando Alvarado ([00:51:53](#)):

No. How do we integrate a system that is growing from the bottom up into a whole grid, while maintaining the, basically, individuality and the ability to, in an emergency or in the security issue, to still have—. But the contract with utilities has to be very different. You can't have somebody in charge. You look at Maui, what happened there? And the utilities are being blamed for it. So now what is their solution? Anytime there's big wind or the possibility of something and dry weather, they cut off the power, they don't want the liability. That's a solvable problem, you know? So I'm getting again on my soapbox, but you ask me, are we looking at something obvious that could be done? And the answer is yes. Let's think about—not about the power grid, and not about power utilities—but how do we provide

electricity for people in the most effective way overall? And industry is the same. Anyway, that's it, that's what I wanted to say.

Sairaj Dhople ([00:53:02](#)):

Thanks Fernando. I'll turn it back to Julie.

Julie Cohn ([00:53:06](#)):

I'm going to go back in time again.

Fernando Alvarado ([00:53:09](#)):

Okay. Yeah. This is supposed to be historical, not future.

Julie Cohn ([00:53:13](#)):

Historical. But we will circle back to this since I know you're passionate about it and we probably all are. I noted that—I looked at the IEEE Explore list of your publications. And the most cited paper is one from 1993, "Point of collapse and continuation methods for large AC/DC systems."

Fernando Alvarado ([00:53:35](#)):

No kidding?

Julie Cohn ([00:53:37](#)):

It has oh, I don't have handy the number of citations, but that is your most cited in the IEEE database.

Fernando Alvarado ([00:53:47](#)):

Yeah. Yeah.

Julie Cohn ([00:53:48](#)):

So my first question about that is, could you give us the thumbnail sketch of that paper for the non-engineering audience?

Fernando Alvarado ([00:53:58](#)):

Yeah, actually, that was one of my very, very favorite papers, for two reasons, and I'll explain them both. But one of them is the fact that that, people basically had all kinds of problems with solving the power flow problem, as you approach the limit capability of the equation of the system. There is such thing as a limit. You cannot—on a given line with given set of voltages, you cannot transmit more than a certain amount of power. The equations become nonsolvable. You cannot solve it by any technique. You get imaginary solutions and all that. But what the problem has always been, the closer you get to that point, the harder it is to solve by conventional Newton techniques. So my solution was twofold. One is to say, "wait a minute, I can very simply do what you guys are doing and almost draw a curve here.

Fernando Alvarado ([00:55:05](#)):

<Gestures to illustrate explanation> You are basically approaching a point where the voltage is dropping, dropping, dropping, then all of a sudden you get to a point that you cannot go beyond because there's no solution. So why don't we replace one of the variables with the voltage, and let's solve this problem with the voltage here, here, here, here, here. And by the way, we can keep going. Because what the power does is does this and comes back down, you know? So I simply change the, the variables. And instead of asking, "calculate the voltage," I give the voltage and give me the solutions or the power that you'll get with that voltage. Simple, very obvious. But beyond that, and I then said, "why don't we just find the very maximum point by formulating the equations of what that point looks like?" So instead of solving for a point by trying to get <Makes sound: breep, breep, breep> to it, I say, what are the conditions that lead to that point? What is that point? So I wrote the equations of that. Bingo, this solved perfectly. Robust, no problem. I forgot about that paper. That was my favorite. And that led to some fantastic little comments from Pete Sauer at one point. But yeah, he really liked it.

Julie Cohn ([00:56:20](#)):

So, from the historian's perspective, I looked at the citations in that paper, and the vast majority had been published in the prior 10 years, with maybe three from prior to 1986. So what had happened that made this topic of interest to people starting in the 1980s, really?

Fernando Alvarado ([00:56:46](#)):

A voltage collapse in Seattle. People did not realize that in a power grid you can see—okay—here's this—very, very simple. Okay, we're getting into real power engineering here. Hmm. Okay, I'll do it with a curve. <Gestures to illustrate explanation> If you go, essentially, when you have a normal system, your

voltage is here, as you begin loading the system, the voltage begins, dropping, dropping, dropping, dropping, the more loading it is, and then eventually it gets dropped fast. And eventually you can't go below. So this is what the voltage is doing, okay, dropping, okay? Now, what people do is they don't like to have the voltage drop, so they compensate the system. So what you end up doing in the system is you add capacitors and equipment to keep the voltage from dropping. So instead of the system doing this, the system does this. <Gestures>

Fernando Alvarado ([00:57:47](#)):

However, you haven't moved the point of collapse. You just don't know how close you are, because when you reach that point, it drops like a rock. And that's, essentially, before it was like this, you know, <gestures> it was a curve and now you make it like this, but the point of collapse is the same. So you can't go past this point just because the voltage looks normal. Okay? So that was, in lay terms, what, what happened in Seattle. They didn't realize how close they were. Point of collapse, a little additional load, and the whole system collapsed. The whole region in downtown Seattle or something. And they said, what happened? You know, there was a voltage collapse situation. There were two or three other incidents like that. Now, the problem, the difference between the voltage collapse incident and a power outage incident, is the power is the entire system or a large region. Voltage collapse can be just a substation, a downtown system, or as Pete Sauer said, "Hey, it can be your electric shaver." Any piece of electric equipment has that limit. And if you drop the voltage enough, you know, it can be very, very small. So it's a localized problem.

[REMOVED FROM THE TRANSCRIPT]

Julie Cohn ([00:59:12](#)):

Then let me quickly ask Dan and Sairaj if you have additional questions you want to ask before we look to the future. And I know Jess will probably have a question also.

Daniel Molzahn ([00:59:25](#)):

I could ask questions for another hour, I suppose, on voltage collapse, because I think this is very interesting.

Fernando Alvarado ([00:59:32](#)):

I'd happy to repeat this at a different time. By the way, I'm retired after all, but go ahead.

Julie Cohn ([00:59:36](#)):

Let's, before we go on, plan that we will do a second interview.

Fernando Alvarado ([00:59:41](#)):

That takes the pressure off.

Daniel Molzahn ([00:59:43](#)):

Maybe stepping back from the technical piece. We had talked with a lot of folks about—because to me, this voltage collapse and continuation methods and these things kind of tie in with some of the control concepts coming out of the control community. And we had talked with a good number of folks who were involved in Les Fink's DOE projects and this sort of thing. From my understanding, you very much consider yourself a power engineer, right? Where then there's this whole other community of folks like David Hill who we talked to, for instance, and Ian Hiskens that really came out of the controls community and were applying ideas into power. So I guess from your perspective, what was that like at the time? You're seeing these different ideas come into the field and people who I think now are very well recognized as power engineers, but maybe at the time were more controls-oriented people. What was the perspective on the power side like?

Fernando Alvarado ([01:00:50](#)):

Well, it's a little bit of what—a comment I made earlier about utilities not being interested on these esoteric concepts until they realize how important they are. So the initial reaction to anybody who comes from a control background that has never seen a real transformer, or heard what the opening of a 245 kV breaker [*345 kV breaker*] sounds like when you are near the substation, or things like that. They have no idea. These are just mathematics and they don't—like what you were saying. But the thing is that when all of a sudden some of the work, for example, by Hiskens on bifurcations, and the idea that some of these things can—my allusion to the fact that you can never guarantee a hundred percent reliability because of some fundamentals in the nature of the system.

Fernando Alvarado ([01:01:45](#)):

They listened a little more. But for the most part, the control people have always been treated with a little skepticism. But let me go back to a historical fact, very historical. To me, one of the most important papers in the entire power industry of the last, of the past century, was the one—who was it? Cohn, Nathan Cohn, on the fact that the time constant—this is the—it was a control paper, basically. You cannot have [*must have*] separate timeframes of control in the power system. You cannot try to control the generators in the same timeframe as the interchanges, for example. That's when you get into instabilities. The time concepts or interchange control between areas cannot be in the same—interact with the eigenvalues of the <inaudible> response associated with the generator, whatever—feedback systems, the governor systems. But if you move to today, you could do instant feedback on power in some of the electronic equipment you have. But you really don't want to. That's kind of what my paper alludes to. And the control people are the brakes that bring sanity to some of the ideas that people could think: "oh, why don't we do this?" Well, it's like flying a plane, you know? It's exactly the plane analogy. You can make it faster, but you're going to make it unstable, and that's the key.

Daniel Molzahn ([01:03:25](#)):

Got it. That's very interesting. And I'd love to dig into that more too. And I'm sure Julie has some thoughts on this as well, but Julie, I'll pass it back to you and let you and Sairaj ask questions.

Julie Cohn ([01:03:39](#)):

We need to respect this time limit. So Sairaj, did you want to ask one more question before we conclude, wrap up for today?

Sairaj Dhople ([01:03:49](#)):

Yes. I do want to mention, Fernando, that's a nice thought for you to offer, especially given the person you referenced is Julie's father. So that's a nice way to, I guess, bring everything together here. But yes, I do have a final question for you, if you will. Do you have any words of advice or wisdom for future generations of power engineers as to how they should structure their lives and think about their careers?

Fernando Alvarado ([01:04:21](#)):

Yeah, my first one is, "think outside the box." I mean, don't let, if you will, "we've always done it this way" be what you think, if you want to be creative. If you want to work for a utility, that's what you need

to do. But if you want to be a creative contributor to society, you need to think outside the box. And you know, the solutions of the future may need a lot more creativity. I mean, to me, the big example of this is the electric car. I'm also not against nuclear power, bringing it back, guys. It's a good technology that was bad-mouthed. But again, think outside the box is my advice. While you still gotta keep a job. So you can't think too far outside the box unless you have a lot of money. But, you know, be creative.

Jess Slater ([01:05:20](#)):

Julie, that goes into the question that I had. Is it okay if I—

Julie Cohn ([01:05:23](#)):

Yes, please.

Jess Slater ([01:05:25](#)):

Okay. You mentioned earlier that a good idea or good technology doesn't necessarily guarantee being picked up. Based on your past experiences, what strategies would you recommend to students for navigating the political or policy aspects of securing funding for new ideas?

Fernando Alvarado ([01:05:44](#)):

Oh, boy. That is—

Jess Slater ([01:05:46](#)):

It might have been a loaded question.

Fernando Alvarado ([01:05:48](#)):

No, that is a very, very, very heavy question. And okay, I'm going to be a little careful here because I don't want to this to be political.

Jess Slater ([01:06:02](#)):

Oh, no.

Fernando Alvarado ([01:06:02](#)):

Yeah. But I've got to say it, because I already put it on paper to a friend and that—basically I'm going to say it—Elon Musk, okay. A tremendously creative guy. Without him, we would not have the electric cars, where we have, the network we have. We would not be thinking into space and all that. And he, I think all he wants out of the world is some recognition. I don't think he wanted all that money. And sometimes when you go at it in a really different, creative way, the world is not going to recognize you until after you're gone. I'm sorry. That's the way I look at it.

Julie Cohn ([01:06:52](#)):

I think there are many examples in history of that.

Fernando Alvarado ([01:06:54](#)):

Oh yeah. And I think we're seeing one right now. You know, you could agree, disagree with a lot. He has an ego. Whatever you want. He has been a great mind with great ideas, thinking outside the box. And sometimes you don't get rewarded for it. You do it monetarily, but I don't think that's what he wanted. That's my own personal opinion.

Julie Cohn ([01:07:17](#)):

Interesting.

Jess Slater ([01:07:18](#)):

Oh, thank you so much.

Fernando Alvarado ([01:07:20](#)):

Okay. On that note, thank you.

[End of first interview]

[Second Interview – November 20, 2024]

Julie Cohn ([00:00](#)):

This is Julie Cohn. I'm conducting an interview with Fernando Alvarado on November 20th, 2024, online. This is part two of an interview begun on October 16th, 2024, also online. Daniel Molzahn will assist with the interview, and Jess Slater is also participating and may ask questions. Dr. Alvarado, during today's

interview, we'd like to pick up a few themes we touched on during our prior conversation, including sparse matrices and voltage collapse, which you discussed with us previously. And I believe Dan would like to begin with a question.

Daniel Molzahn ([00:40](#)):

Yeah. So, Fernando, again, we really appreciate your time and thanks for coming back to chat with us again. We talked a little bit about sparse matrices at our last discussion, and I think this is super interesting because it's an area that power engineering was really at the forefront of. I'm wondering if you can kind of characterize that a bit—how much of the technology that was being developed at the time was—is maybe still used in the same packages today? I mean, where—is that still—if I opened up the linear algebra packages that I would find on my laptop, are they written by Bill Tinney? Or at least very inspired by Bill Tinney still? Or has there been a lot of work since then?

Fernando Alvarado ([01:26](#)):

I would say—let's see. Let me answer that. Clearly a lot of the current packages, both in the linear algebra community, possibly even in some packages such as MATLAB, and some of those, will include, if not the direct code, the ideas, you know, from Bill Tinney. In parallel with Bill Tinney's work, there was some, a lot of work done on SIAM's work as well—the Society of Industrial Applied Mathematics. I don't know if you're familiar with Iain Duff. He's a person from that numerical community—kind of took the mantle and moved forward—written some books and everything. And the mathematical community has always been kind of picky about their choice of people that they acknowledge. But they do acknowledge Bill and the contributions of power, but in a lesser way than I expect this should be done.

Fernando Alvarado ([02:29](#)):

They still have these conferences, Sparse Days in St. Giron, in France every two years. And that was still very active. I got invited to the next one. I attended one or two. But there was a recognition that Bill Tinney was a very good guy, and some of the original code from power may still be in some of those, but I don't think the code in the mathematical linear algebra packages is a verbatim rep—. It came directly from Bill. The ideas were greatly influenced by Bill. Now in the power community, that's a different story. I suspect that some of the packages out there, and I can—I'm almost a hundred percent sure—contain original code in one form or another from that developed by Bill and others. I know for example, that one of the packages out there may contain a few lines of my own code.

Fernando Alvarado ([03:26](#)):

I don't know if it's the most commercially successful, but I do know that there's code directly. After all, one of the things that happens is professors tend to teach, and the objective of teaching is so people learn from you and take that and use it in their careers and lives. And some of these things that were not directly copyrighted, having used almost directly out of homework assignments, out of projects the students did. And I know for a fact that, for example, indirectly the entire Power World, as developed by Tom Overbye, came—not the code, but certainly all the ideas or the practical ideas that were implemented in that code—came indirectly from Bill Tinney—and through me, because he was my student in one of my classes, several of my classes.

Fernando Alvarado ([04:20](#)):

So the answer is not as simple in the—. To summarize: in the numerical analysis community, there's recognition of Bill Tinney, but not to the degree that I believe he deserves. Because—it was some independent developing going on there that gets a little more credit. In the power community. I think a lot of the code is directly—in fact, most of the code today is directly relatable to Bill Tinney and the early efforts of several people that were working in the area. To the point that some code may still be in use,

Daniel Molzahn ([04:53](#)):

That's really interesting. And I wouldn't be shocked if some lines of code are still in use. So maybe to follow up on this quickly, what was it like being—working in that setting? Were the numerical analysis researchers and the power engineering researchers—did they show up at the same conferences? Did they know each other? Or were they really, kind of, very separate groups that—somehow Bill's innovation broke through? But it's not like they were getting coffee and beer together all the time.

Fernando Alvarado ([05:26](#)):

There were a few of us, starting with Bill Tinney, really, that recognized that there was a correspondence and the ability for synergies between—. Power people clearly were the ones with the greatest need and developed the practical code. And not necessarily all the theory that was to go into these codes. But the mathematicians take a different viewpoint. They're more rigorous. They tend to do more analysis. They tend to be—and they do want to develop these very general-purpose packages. And they did it over the years. But, I know, for example, I could be wrong, but I believe the earliest effort of collaboration was

between Tinney and Erisman. Al Erisman, I believe. And he, I believe, came from the mathematics community.

Fernando Alvarado ([06:21](#)):

Bill referred to him as SIAMers—Society of Industrial and Applied Mathematics. And I'm still, as a result, a member of SIAM. I've actually been invited to SIAM conferences—awarded many, many years ago—before I kind of abandoned the sparse matrix as my main topic of interest, and it just became a tool rather than an area of direct research interest. That's what happened. That's really what happens to all successful areas in the development of the world. When something becomes good enough and practical enough, the next step is: commercialize it, use it, and it's no longer the subject of primary research. And that's where we are today. I mean, there are side things, little things you can improve, but the primary work is done. But there was collaboration, as I said, through this conference. So some papers are published in the numerical analysis community.

Fernando Alvarado ([07:17](#)):

And there's—the clearest example of this is MATLAB. MATLAB basically integrates now a fantastic set of sparse matrix tools. You really almost don't need to program anything. With one or two exceptions. There's still no, as far as I—and I work with MATLAB, you know, occasionally—I still don't think there is something that Bill developed—and I helped on that very effort—something called "sparse vector methods." The sparse vector methods are not quite implemented. I don't know why. Maybe they're there and I haven't found them, but I've never found it to be essentially practical. The other thing that I have not seen, and it should be a basic command in MATLAB, and it was another great aspect of the work done by Tinney and others of the time, so that it was part of it, but I don't necessarily mean the main idea—but it was the sparse inverse.

Fernando Alvarado ([08:17](#)):

The sparse inverse is a very unique thing. The inverse of the sparse matrix of a connected network is full. So if you have 60,000 buses, you end up with a 60,000 by 60,000 matrix, which, if you're not careful, it's going to be singular and you won't invert. But, you know, an inverting matrix is usually a very bad idea. First thing I teach my students is you don't want to invert a matrix. You want to find a solution to a problem. And inverting the matrix is not the way to do it. So that was the number one thing. This idea of

Z-matrix that was done in the early days. People inverted the network admittance matrix to obtain the impedance matrix, and then they could find anything they wanted easily.

Fernando Alvarado ([09:08](#)):

But those matrixes tended to be enormous, and very hard to keep around. So we discovered, or people discovered really, that you don't really need all the elements on the inverse, just a few. And in order to get just a few, you really tended to need only the elements of the inverse of the matrix that corresponded to the non-zeros of the original matrix, even though every other number was there, and non-zero, you didn't care about it. So, was there a fast way of getting a subset of the inverse? And the answer is yes. The sparse vector methods did that, with a caveat. You ended up getting a few extra entries that you didn't really need, but without getting them, you couldn't do it. It wasn't doable. It had to do with elimination trees. You had to create elimination trees that ended up producing as many, as few extra entries. So that's an example of something that even today, I am not sure the community outside power engineering is doing or cares about. So those of us that are in the area where one point you know, we know we can do better in our specialized problems, but maybe nobody else has a need for sparse inverse, maybe, but we do. So, it's in most of the power codes that would not be in the libraries. I haven't looked too much recently, but the last time I looked, I couldn't find them.

Daniel Molzahn ([10:44](#)):

Yeah, I've looked as well, and I've never seen that in MATLAB. At least I have my students try to implement some aspect of it themselves. And yeah, you're right, you have to—. That's interesting that that seems to be specific to our area because it seems like a fairly general concept, but maybe—

Fernando Alvarado ([11:00](#)):

Yeah, I think there'd be no reason why MATLAB couldn't implement a sparse inverse. [*MATLAB has not implemented a sparse inverse as of December 2025*] Just no reason why. But I don't want to encourage them to do that, because that kind of increases the competition for people. I mean, it's one of those things that: they want to do it, they don't want to do it, that's fine. We have the code. But one of the practical things is that these days things are so fast, orders of magnitude faster, that for most practically-sized power problems, it's not a huge showstopper anymore. If you have to do the—if you don't have that capability. It used to be critical. And right now, it'd be still useful. In fact, right now I am actually in

the process of using it for a particular little analysis I'm doing for our little company here. So, I'm rediscovering some of our own code.

Daniel Molzahn ([11:57](#)):

Oh, very nice. Maybe one other question here, and then I'll pass it over to Julie, because I know we have limited time with you. But you touched on, you mentioned this a little bit, that the technology gets developed to the point where it becomes, kind of, a tool. And so how long did that take in power systems? I guess in sparse matrices in particular, were you immediately transitioning to saying, "we need to apply this in state estimation and unit commitment and OPF and all these different applications?" Or was it, "this is for power flow, we're going to spend time optimizing this methodology first, and then we'll apply it elsewhere?"

Fernando Alvarado ([12:41](#)):

I think there was a bit of both. I think the development of the basic tools to—some efforts, some years, people—sparse trees—working with elimination trees, reducing their width, the length, whatever—those are basic ideas. The idea of a W-matrix, which—that is my own creation—the W-matrix, which is essentially: if you have to invert a sparse matrix, you don't invert it in its entirety. You invert it in segments—into 2, 3, 4, 5 things that you multiply together, give you the inverse—and you retain an enormous amount of sparsity and a lot of parallelism comes along the way. That tool is another one that hasn't been developed and used as much. [Enns, M. K., W. F. Tinney, and F. L. Alvarado. 1990. "Sparse Matrix Inverse Factors (Power Systems)." *IEEE Transactions on Power Systems* 5 (2): 466–473. <https://doi.org/10.1109/59.54554>]

Fernando Alvarado ([13:31](#)):

And it's not really available outside of the industry. And it may still be practical, but—so there's still some fundamental ideas out there that are not everyday tools. But the big shift in my mind— I used to teach a course, co-taught, it's the only time I've actually co-taught a course with Computer Science—Computer Science was very interested at the time in this. And we had a course that I had created for Power Systems, 722 at Wisconsin. And it was co-listed with Computer Science, and we shared the classes with Michael Ferris, who was a very well-known optimization guy in Computer Science. So, we had some good years of that. But that was on the fundamentals side and track, a little bit. The other one was a question of the application. What was the second part that I was trying to address?

Daniel Molzahn ([14:25](#)):

How fast did they get adapted into all these other applications?

Fernando Alvarado ([14:30](#)):

To me, the final thing was when I saw that MATLAB could do pretty much everything, except some of these fancier tools, W-matrix trees, sparse inversion, but pretty much everything else could be handled so much easier, no code to be written. And at that point is when I think it became a, you know, a "pencil," a tool. And a tool that everybody can use without knowing anything about or caring even about sparse matrices. You've got to know a little bit, because otherwise—I've seen code that is terrific code, works great on systems of 30, 50, 100 buses, but it breaks down when you go over 300. Why? Because they didn't think about sparse matrices. I see code all the time, well, not all the time, but every time I look at somebody's curriculum or something, that happens, but with a little bit of care, you no longer have to do fundamental—be a researcher in this sparse matrix area—to be able to use this effectively. And that happened, I would say in the '90s, it began to happen. And by 2000, it was pretty much: why bother with an entire course on sparse matrices, unless you're going to be a specialist on that. Most everybody wanted to solve power system problems, not sparse matrix problems, you know? So once you get to the point that it was more practical to simply just do it with libraries, or do it with MATLAB, it became less of an impetus.

Daniel Molzahn ([16:00](#)):

Julie, I was just going to add, I took that class when I was at Wisconsin, with Michael Ferris, so I appreciate you putting together, it was very, very fun class. Sorry, go ahead.

Fernando Alvarado ([16:12](#)):

You know, when I said that, I was thinking exactly that. I said, hmm, I think I had it in the back of my mind, whether you've been in that class or not. Thank you for reminding me.

Julie Cohn ([16:28](#)):

So, when Bill Tinney first addressed this topic in publication, most power companies, most utilities might have had some kind of analog computing hardware, a few might have digital computing hardware. And wasn't his solution primarily usable on digital computing hardware?

Fernando Alvarado ([16:53](#)):

Well here is the timetable, if you will. Before computers even, people had to analyze power networks. What you did is you created a miniature version, scale-model of a simplified network with resistors, impedances, and you put it in a lab. Because these systems kept growing. It became a good idea—and the system became more interconnected—to have very large-scale simulators that were hardware. And at a few specific locations. Wisconsin was one. We had a lab, which I can tell you, became my office basically, where we had a simulator. Where the utilities would come once a year and study all the possible cases they would want to do it for the year. And at that point, it became—it was a very uniting force among utilities and universities because it was a logical place for having a coming-together and analyzing.

Fernando Alvarado ([18:02](#)):

So it brought experience into the university, rather than people having to go out. But then came the very, very first programs that were able to solve the power flow problem. And you can write, in 10 minutes, enough lines of code to solve the power flow problem without any sparse matrices, using something called the Gauss-Seidel method. It wouldn't always converge. It wasn't suitable for our systems. It had its own problems. But lo and behold, it worked in many cases, and it worked well. And at that point, people began using—let's say it was easier to use a mainframe computer with a Gauss-Seidel iterative solver, than to go into setting up one case on a hardware simulator. Okay. And that came, that began the complete transition from analog to digital, with one exception— transients, and especially electromagnetic transients, were still a decade or two away from being transitioned out of the analog world.

Fernando Alvarado ([19:11](#)):

Even today, I think there's still a few analog simulators for transients, although I'm not sure if there are any left. This is an EMTP story. The Canadians, IREQ, had a lot of that to do in Manitoba. Canadians were doing still a lot of that. And, but that's two decades later. Then it was found that, even though everybody was rapidly transitioned to digital, the digital methods available were not adequate to reliably solve large problems efficiently. And at that point, Bill Tinney came and said, "Hey, wait a minute. The best method possible is Newton's method." Yes, it is. It converges well, when it converges. Then there were all kinds

of issues of convergence. I was involved in a lot of that. The point-of-collapse method was a way of saying, "Hey, this problem is solvable."

Fernando Alvarado ([20:09](#)):

In fact, it's so much solvable that we can not only find out when the problem is not solvable, we can find exactly the point at which it becomes unsolvable, precisely. So that was all side effects. It was not the mainstream. But the problem with Newton's method, of course, was that it required these big matrices, and bigger and bigger and bigger. And at that point is when sparsity, it became the heyday of sparsity. 1967, I think, was the first practical use of sparse matrices. In fact, the paper we discussed last time, to me, one of the seminal papers in the power area from the 20th century. That's the one that kind of said: well, okay, here's Newton's method and here's how we can use it. And that changed everything. Because at that point, you have a reliable solver that could solve any size system. And at that point, I think, all simulators that were doing steady-state analysis became obsolete. Anyway, I could elaborate, but I think that's my take on the history of simulators and the two-step movement, three-step really, first to the Guass-Seidel method, then to Newton's method, and then to Newton's method with sparsity. That was the point at which things really changed.

Julie Cohn ([21:36](#)):

Yeah, I guess I was wondering to what extent adoption by utilities would've been delayed until they were also buying new control room computing equipment, new backroom computing equipment, that kind of thing.

Fernando Alvarado ([21:53](#)):

Well, it really was hand-in-hand with computers. I mean, there was initially a resistance to go digital. I mean, people like the feeling of knowing, seeing meters with—<gestures to illustrate>—you move something here and all of a sudden, the flow changes here. And to this day, a lot of the, see—initially the digital solution was just printouts on a piece of paper. And then came visualization tools. Power World is an example of something that people said, "oh, wait a minute, we can actually visualize this a lot better." Not that Power World brought to the world a lot more computing power. It did. It had very good techniques, great methods and everything.

Fernando Alvarado ([22:45](#)):

But before Power World, there was PTI. And PTI, excellent software, but they didn't have the visualization capabilities. Once they came into the picture—of people being able to show it to your CEO, "this is, you know, what's going on in your system," then at that point, it really changed the need for having digital, I'm sorry, analog things. And it was, again, a more gradual process of getting there, but not so gradual. These things always happen. And then you move to the next level. The conversions issues of Gauss-Seidel almost—were fighting dead against a lot. There was a lot of controversy at one point in history between Gauss-Seidel and Newton's method. And I remember, when some of the utilities were still coming to Wisconsin in person at some point, and they were basically saying, "oh, no, no, we don't trust Newton's method because it won't always converge," or something. And that debate eventually went away. I mean, it's just—the only advantage of Gauss-Seidel is you can program it in five minutes.

Julie Cohn ([24:01](#)):

Thank you. Dan and Jess, did you have any more questions on this sparse matrix topic?

Daniel Molzahn ([24:10](#)):

Well, maybe not on the sparse matrices directly, but on something you just said, Fernando. So one of the things that we had talked with other interviewees about was how the development of optimization in the '90s sort of helped enable the development of electricity markets at the wholesale level around that time. And from what I understand about the history of Power World, and the history of visualizing, instead of, as you said, instead of printouts, where numbers—had pictures you could show to CEOs. Was that influential in the development of electricity markets as well, in the same way that optimization was? That you could show an economist: here's how the flows on the system work. Or was that purely an engineering thing?

Fernando Alvarado ([24:53](#)):

No, I think the ability to show—actually, interestingly enough, now that you mention it, the flows to an economist are incidental. They don't care about flows. They care about prices and the impact on the efficiency of the system. It is a very interesting thing that I always tell everybody. It is incorrect, totally, completely, 100% incorrect to say that before markets, systems were being run inefficiently. Systems were being run optimally. They were. Because even though we engineers did not acknowledge, this idea of using penalty factors, and essentially an optimum power flow, produces an exact same dispatch pattern—this is without any markets—that you would do today with an optimally, perfectly designed,

much more complicated market. So the reason for going to markets was not to operate the system better. I strongly believe that. That systems were being operated as well as possible.

Fernando Alvarado ([26:10](#)):

Now, what was lacking is the ability for other entrants to come in with new ideas, with innovation. Innovation has never been the forte of power utilities, simply because of their regulatory status. They make money based on the invested capital. They justify operation of the power system. It's always been nearly optimal. So—I don't know where I was going with that one. The—oh, yeah, —understanding the markets. The earliest thing that came on, in my opinion, and again, I'm a little biased because I'm the one that pointed it out, and that is that from the Jacobian or Newton's method, you could determine, essentially, the Lagrange multipliers, which in effect are the prices for the system.

Fernando Alvarado ([27:04](#)):

This was a realization that's very simple. The transpose of the Jacobian will give you the Lagrange multipliers that you need to dispatch your system. But what is different in the markets is, once you have those numbers easily computed, you can put them out there, and then people are working with bids. If you can bid your generator below the price at that location in the network, your generator will be dispatched. If your price that you bid is above the marginal price of that location, your generator will not be dispatched and you won't be making any money, and you won't want it to be dispatched. Trust me, because then you'll be losing money. And it took Bill Hogan to realize, and he's an economist, the first economist that actually understood the constraints and flows in power systems.

Fernando Alvarado ([28:01](#)):

He said exactly what engineers have been saying all along, but he said it in economics terms, and people believed him and listened to him. And, you know, that was the conversion. Not that the engineers didn't do it, they were doing it all along. But Hogan was able to explain it in economics terms, and he still had a hard time convincing people. To this day, he's still very active, I believe he's still very active. And the other thing is a statement I heard from a very famous professor at MIT, an adjunct professor at MIT saying, "well, you know, these nodal prices, you can visualize, you can see them, but they're random. They seem random." And it's the furthest from the truth. It is not, they're not random.

Fernando Alvarado ([28:52](#)):

They are very peculiar. They have funny patterns. They are not intuitive. That's one thing. They're not intuitive. <gestures to illustrate> If something congests here, you end up with a spike price here and a very low negative price over here, which actually tells you that you should be consuming here, and that'll be good for everybody. Good for the system to put a load there right now. But somehow there's a taboo against this. There's just, people won't do it. But the right thing, the right pricing under some congestion conditions—and this is one of my pet peeve these days—for example, that would be the perfect time to charge batteries. Get paid to charge your battery, and it's better for everybody. It's better for you, better for the utility, better reduces congestion. It's just fantastic because these things change with time, change with the congestion pattern. But there are situations that are so counterintuitive to the economics world that to this day, there's still argument.

Daniel Molzahn ([29:51](#)):

I show my students pictures of negative prices, and they're always very surprised that that's a thing that can exist. It is somewhat counterintuitive, but you're right, they're certainly not random. They're very much not a random thing. I had one other question for you that related to something you'd mentioned earlier, talking about the hardware simulators and how EMTP models took a little bit longer to get digitized. One thing that—we had talked with Deepak Divan early on in this project as one of our interviewees, and he was talking about how, at Wisconsin, a lot of the ideas he was coming up with for droop control and microgrids were related to machine control. And there was all the machines folks at Wisconsin. How much of that influenced your work, being in an environment with lots of machines and power electronics folks around that were building hardware and doing physical experiments? Was that something that really influenced your work in this space?

Fernando Alvarado ([31:04](#)):

Not as much as you would expect, because I was always aware, ever since Cohn, I believe, the guy in the '50s that wrote the book on controls, I forget the name now. Anyway, the fact that you really do need some droop in order to stabilize the system. Otherwise, you end up with too many extremes of control. The fact that things don't respond. I mean, we've always been aware of: machines don't respond instantly. The most important one in recent years, and I was advocating it for years and years, it was essentially the impact that generators have on the system in two regards that most markets do not normally consider. And one is the value of inertia in the system.

Fernando Alvarado ([31:58](#)):

The fact that you have instantly available a certain amount of, little bit of, energy distributed over the grid that is going to keep the system stable. If you make it purely electronic, and don't take that into consideration, you're going to have a problem. As long as it's a small penetration, it's not a problem. But as long as it's a large penetration, it's a problem. The second problem—there is actually a third problem there, too. But the second problem is the time constant issue. I think I wrote a paper at some point in which I basically said, "can you control a system entirely by prices?" And the answer is yes, but if you're not careful, and if you don't put the right delays in the feedback mechanism, you could end up with an Eigen value on basically an unstable system.

Fernando Alvarado ([32:51](#)):

You can destabilize a system if you don't put the correct time constants in the feedback loop that is leading to the market responding. If the market response is made too fast or too strong, you basically will end up having a system that looks at the prices, everybody's now generating more because the prices are higher. And then of course, the prices immediately drop, people begin generating less, and then all of a sudden, "oh, whoops, we overdid it," and you end up <gestures and makes a ne-ne-ne sound>. You know, it's a classic instability that used to be caused by generator controls. But in today's market, and electronic controls, when you begin abandoning machines, you end up essentially creating the potential for new problems. I think Deepak and other people—I've always said to them, when I discuss things with them—that the idea is even though you're able to do more things and faster with electronics, batteries, solar, and other electronic components, you may not want to. You may want to, to a certain extent, simulate or emulate, not simulate, what generators used to do.

Fernando Alvarado ([34:16](#)):

Only you can do it better. You don't have to do exactly what they used to do. But because you have the capability to respond really quick to something doesn't mean you should. And that's kind of the idea and the connection to—I don't know where exactly he was coming from—but the idea that with electronics you can do so much more. And machines have always been part of the process. The other thing was voltage control. You get voltage regulation in a distributed manner with generators, that is more or less—goes with the territory. Nobody ever questioned it. At some point of course, with the new electronics, and this was early on, the early models of the wind generators were nothing more than

induction motors, induction motors working in reverse. Well, characteristics on voltage of those things are horrendous.

Fernando Alvarado ([35:14](#)):

Not only they don't regulate voltage, they actually consume it at the wrong times. It's just horrible. So all modern, no modern wind generator uses a simple induction motor anymore, because it is terrible voltage-wise. To the point that, a fellow—really—he's really a good economist—Dick O'Neill said, "Hey, why don't we put a market on reactive power?" Which is what regulates the voltage. And I said to Dick, "I agree with you on most everything you say about markets, but I don't think it's a good idea to put a market on reactive power." And my analogy to him was: just because you can do it, it doesn't matter, because the value of reactive power at the location is either going to be zero or infinity. And this is my analogy: would you put a market price on lift on an airplane?

Fernando Alvarado ([36:12](#)):

You won't go off the ground without it, you know? And if all of a sudden you have too much, it doesn't, your plane goes up. And you can't have too much <gestures to illustrate> you've got to regulate it carefully. You don't put a price on that. Okay. I mean, you can. But what you really want, there's certain things that just don't make sense to put in markets. Now, you could pay for capability to regulate voltage, that's different. Anyway, I'll leave it at that.

Daniel Molzahn ([36:46](#)):

I love that analogy. That's a really nice analogy. We talked to Dick earlier in this project too, and reactive power markets didn't come up, but I've always been curious about those discussions too. But I do want to make sure—I've been asking lots of questions. Let me pass it over to Jess or Julie to see if they have follow-ups.

Julie Cohn ([37:06](#)):

I had one more related to the sparse matrix topic, which is both in the list of, or the timeline you shared with us about this history. And also in our prior interview. You mentioned that you personally worked on a genetics project. Can you just tell us for a few minutes what that—

Fernando Alvarado ([37:25](#)):

Yeah. You might see my name on a paper on that. This was a sparse matrix thing. I forget the guy's name now. He moved to New Mexico with his project. And he was a professor in the Ag school. And he'd actually been aware of my efforts in sparse matrix. And what happens is, in genetics, you try to predict the capabilities of a cow—in Wisconsin it was always cows, you know, because it's cows in Wisconsin, that's sort of the symbol almost. But you look at the parentage for characteristics and features, and you look at 10 or 20 features of each cow, the parents' parents' parents, and then you end up creating a—what normally would've been a tree. But because there's crossbreeding, all of a sudden you have the same matrix of parentage that a power system would, because some things connect again, you know, so you no longer have a tree, which trees are easy to analyze.

Fernando Alvarado ([38:28](#)):

But once you begin looking at parentage crossbreeding, and you are trying to solve for 10, 20 characteristics of the cows, looking at the 20 or 30 characteristics of each one of the parents, then you need—and you're looking at tens of thousands of these, now you need sparse matrices. And so he came to me and I set him straight on things he could do and he couldn't do and all that. And by the way, one other thing that, when you said you have looked at my references, I never looked at my previous references or referrals or something. I was a little surprised myself at some of the things I saw. One of the very surprising things I saw there is I seem to have a lot of citations, no references, on a program called EES, Engineering Equation Solver, which is essentially something I contributed to this mechanical engineer that was into thermodynamics, Sandy Klein.

Fernando Alvarado ([39:15](#)):

And he had written a program to essentially solve thermodynamic problems. You enter two or three of the parameters and the thing solves. But he realized that his program was way too slow. And I had a similar program called Solver Queue, which I marketed for a while. And—long story on Solver Queue, I still have a copy of it, but it doesn't work anymore because they keep changing the operating system and it wasn't worth it. But you basically wrote a set of equations up to, oh, I'll say 60-, 70-, 80,000 equations—nonlinear, type them in, or enter them automatically, and push the word "solve" and you solve it and find the Jacobian, and find—

Fernando Alvarado ([40:14](#)):

It was symbolic computation, and it could solve any size system of equations, period. And I even applied it to power systems, machine equations, a bunch of things. It didn't catch on as much as I thought it would. So I eventually ended the effort. It was too much work, not enough reward. But, EES apparently became the standard for any mechanical engineer, E-E-S. My condition at the time was that my name would be forever associated with EES. Well, eight years later or something, Sandy said to me, how much to buy you out? I guess he wants me out. He wants all the credit. So I said, "so much," and we agreed to it, and now it's a hundred percent his. But it was entirely based on sparse matrix techniques, developed for power systems.

Julie Cohn ([41:07](#)):

Thank you.

Fernando Alvarado ([41:08](#)):

You can look it up.

Julie Cohn ([41:09](#)):

Yes, we will.

Daniel Molzahn ([41:12](#)):

I've used it, Fernando, and Madison. Yeah. Yeah, I remember that too. Yeah.

Fernando Alvarado ([41:16](#)):

Did it have my name on it or not, when you used it?

Daniel Molzahn ([41:19](#)):

I don't remember that. That I don't remember. But I do remember—

Fernando Alvarado ([41:22](#)):

On the opening splash screen, it said Sandy Klein and Alvarado. That was the condition. But then, as I said, he got tired of that. I stopped contributing. I just contributed the solving engine, and that was it,

you know—the solver, which was taken out from our systems. And then, as I said, after a while, he didn't want that there. We came up with a price and I walked away.

Julie Cohn ([41:48](#)):

Thank you. In the interest of time, I'm going to invite Jess to ask you a question that again follows up on something we discussed last time, and that had to do with research funding and new out-of-the-box thinking.

Jess Slater ([42:06](#)):

Yes. Actually, Julie I had a question regarding the students based on what's talked about. Can I ask that one first and then the funding one? Okay, perfect. Thank you. You mentioned that people were initially reluctant to use digital solutions because they like the feeling and seeing the physical models. So while digital tools like have allowed you to visualize and make it accessible to CEOs, do you think students today lose something by no longer being taught with physical models as a core part of their curriculum?

Fernando Alvarado ([42:41](#)):

Yes and no. Yes, in the sense that there's always the need to have—to realize what it is you're dealing with. One thing is to look at the number on paper and equations, and even at errors. Another thing is to realize what a hundred megawatt looks like, what these breakers do and how they sound when they open. And the scale is really the main thing that is missing. Even the labs at the university don't convey the significance of what we're dealing with here. We're not dealing with small amounts of power. We're dealing with very large amounts of power. And I really think there's something missing in that, not necessarily by not having the scale model, but somehow relating equations, flows, and things like that to physical large objects out in the field. Solar panels, everybody sees solar panels, but substations and all that. Not so much the physical flow modeling and looking at the flows. That is actually done extremely well now. And I don't think anything is missed by not having an analog simulator, but the scale of the problem is very hard to do.

Jess Slater ([44:05](#)):

Okay. Thank you. Thank you. And then to follow up, what advice would you give to young researchers to get their ideas in front of potential funders and to get them approved?

Fernando Alvarado ([44:17](#)):

Oh, boy. I'm not sure on that one. I mean, the funding goes with the winds. That's a tough one and let me think about it for a second, because it depends on what you want the funding to do. And to me, there was a—I don't want to sound too negative, because they funded us for years, and they had a mission, but there were two completely different, maybe three completely different ways of funding research in power. One is the utility model. And the utility model was essentially set in concrete when they created the E-P-R-I, Electric Power Research Institute, with its own institutional bureaucracy and big things thinking. But it was intended to address utility-specific research problems. Remember, I didn't say innovation. It doesn't, was not intended to, and I never saw them as true innovators.

Fernando Alvarado ([45:29](#)):

In fact, on the contrary, they were non-innovators. They were anti-innovators at one point. When I proposed to them to do something into looking at, "how could you use pricing to control the system better?" They basically turned me down flat. In fact, they treated us as a threat. "Pricing, we don't disclose our prices." So things like that—it was just like, okay, I stepped on toes there. So anything new—but they wanted to be able, for example, how they could do something they were already doing better, rather than thinking outside the box. There was—to this day, perhaps—no outside-the-box thinking, because the incentive is not there. The utilities are not into changing the model. They like the model; they just want to do it better with that model.

Fernando Alvarado ([46:16](#)):

But if you propose a different model for dealing with the world, they're not going to be interested. That's not in their DNA, you know. And then the second component of that was, of course, the Department of Energy. They were interested in big-scale problems to keep the labs fed. They really work on good things, a lot of data, good capability. And that's actually—reliability of the system was a big, big project—source for that. And, as long as you can keep it big-scale, practical, significant—the CERTS effort by DOE was a very significant one, it was part of my career, actually, created our lab at Wisconsin for power systems and all that. And that is a different level of research funding. But the question is, that's very political—that goes and comes and goes with the Department of Energy.

Fernando Alvarado ([47:12](#)):

And we don't know if we're going to have a Department of Energy next year. We hope we do, but maybe it's not a necessary function of the government. I don't know. But that's a concern. And the third one is, of course, science, National Science Foundation. And that is where you truly can get innovative ideas funded, if you can convince enough peers. The problem with NSF funding is it has to be science, it has to be innovative, but you cannot be too far out there. Because then your peers would say, "huh, what's this?" And back in the day, when I proposed having a complete redo of the entire relaying system in the US according to new principles, they said, "are you crazy?" I said, "okay, I tried, you know." And the thing is, you can be outside the box a little bit more, but you can't think truly outside the box.

Fernando Alvarado ([48:05](#)):

So right now, the concern and the advice I would give is any research geared toward a more sustainable power provision to the world is really what I would think is significant and somebody, that's what people should be trying to do. Whether it's EPRI, whether it's DOE, or whether it's NSF, because we need to change the way we produce energy in the future, whatever it is. But you need to look in that direction. The recommendation I give to all people that are young, is saying, "well, this is, this is your world now, and this is where I think you should be thinking."

Jess Slater ([48:48](#)):

Thank you. Thank you. I did want to ask, how would you recommend to students to fall between that line of being innovative, but being able to convince our peers? Because a theme has been just because it's a good technology doesn't mean it's going to be the one approved. So I'm just curious, how do you find that line for future researchers?

Fernando Alvarado ([49:10](#)):

The first one is be prepared to fail. Okay. Don't get too discouraged and just stick to your principles. And if it means that you can't grow as much or—but again, different people have different objectives, different parameters for their own things. But try to match, try to understand the interest of the person that's going to be funding you with what you are trying to contribute. Don't just have an idea. And yeah, in fact, this was one of my errors in my career. I didn't always match. I had a great idea. My opinion was great. I tried to put it out there to pretty much anybody. And if you don't match the—if you don't understand where the person is coming from as to what they are going to be interested in, what is motivating the institution, not the person, the institution, then you're not going to get funded.

Fernando Alvarado ([50:14](#)):

Maybe a great idea, but it's for the future. So don't go too far out. But try to understand. If it's NSF, what are they looking at? And try to go beyond, try to be innovative. If it is Department of Energy, you know, look at what their goals are. If it is EPRI, if it is your local utility, try to understand it. And if it is an environmental group, try to understand whatever it is. You're going to try to match what you are trying to—don't change it—but try to match it to what the objectives of the funding institution is. That would be my best advice, I guess.

Jess Slater ([50:49](#)):

Thank you so much. And I'll pass the torch back to Julie. Thank you.

Julie Cohn ([50:53](#)):

Thank you. We have just a couple of minutes left, so —

Fernando Alvarado ([50:57](#)):

I can go a little over, but I've got to prepare for a call in about half an hour. And my call is in half an hour and I need to prepare for it. So I've got another 15 minutes if you have them.

Julie Cohn ([51:06](#)):

Okay. We have—so looking ahead, you've talked about some foundational solutions to keeping power systems operating and optimized, and you've mentioned some of the changes ahead as we have increasing presence of electronics-controlled devices, both on the generation side and on the user side. Of the solutions that you've been involved with in the past, do you see some of those becoming obsolete? Do you see some of those continuing to be essential? And do you have any other thoughts you'd like to share about what we need to be considering for the next generation grid?

Fernando Alvarado ([51:54](#)):

Well, one of my things is— I'll address two things. One is part of the solution that I see as the future is the idea of microgrids—widely, broadly defined. In other words, rather than having a single interconnected entity that is the do-all/end-all, you design, you begin evolving into much more completely defined integrated grids—microgrids—that are sufficiently capable, to the point that

perhaps, someday, the system could be split completely and is able to operate. That doesn't mean operate optimally. Okay? Interconnection, the main argument for interconnection is so the entire thing works better, rather than any one, so together you can do more. But the idea that you can function separately is one of the directions that I see.

Fernando Alvarado ([53:00](#)):

The other one is, and this is my national security pet peeve, if you will. And that is that while I don't mind the large-scale solar fields owned by utilities and all that, and they do need some battery, perhaps storage capabilities to make it more uniform. I think what makes more sense, or at least some sense, today, is distributed storage. Because distributed storage will give us a lot more resilience as a nation. Distributed storage will give us the ability to become somewhat independent of the grid in a pinch. And what the dangerous part of utilities is, some people might say, well, I'm now self-sufficient. I don't need you. Now, that can probably happen in the right locations, in the right income categories, the right geographic locations, and independent households.

Fernando Alvarado ([54:03](#)):

But it won't always happen in, like, buildings. Certainly cannot happen in some factories and things like that. So it'd be much harder. So I don't necessarily want to promote that as a do-all/end-all. But I think the idea that customers, as opposed to rate payers, and I'm very objectionable to the idea of rate payers. I think end users have got to be treated as customers, and that is empowering customers. I mean, that sounds a little, you know esoteric, but empowering, allowing customers to empower themselves is in fact a very important concept. The idea that people should obtain, be responsible for some of their own security. And that's a big change in mind. And it's happening right here in Hawaii. I'll give you the specific example. Fires. The Maui fire has drastically changed the way people think around here, at least the utilities do.

Fernando Alvarado ([55:06](#)):

Now, when there's the smidgen of a thought that there might be a potential dry condition leading to a fire in an area, they cut the power. So now you're on your own for the next three hours. High wind, dry conditions, line that—maybe the trees are in trouble. We're not going to power it, because otherwise we'll have a huge lawsuit. Well, what does that mean? That means that, you know, 3000 customers just

lose power. Now, among those 3000 customers, I have about three or four friends that have batteries.

[REMOVED FROM THE TRANSCRIPT]

<Recording Paused>

[REMOVED FROM THE TRANSCRIPT]

Fernando Alvarado ([56:01](#)):

I know three friends that have batteries. One of them doesn't have a very good system, a great big-size system. Unfortunately, it requires a mechanical transfer switch. And he has a big glitch every time it happens, which happens about twice a month now. I have to restart these pool pumps because I designed them to be restarted remotely and all that. But it can be done a lot better. But the point being that short power interruptions should be totally transparent to users. That'll be a better goal, better national goal, than the goal of having a hundred percent reliability from the utility for everybody. And the cost will be much lower. And it'd empower people to survive short outages. That'd be a priority for me.

Julie Cohn ([56:52](#)):

That's very interesting. Thank you. We really appreciate your time in this interview. Was there anything else you wanted to share with us as you reflect back on your profession and look ahead to where you're going next?

Fernando Alvarado ([57:09](#)):

I basically hope that we have a good crop of future thinkers and engineers that will help. I think we need to bridge a little more the gap between economists, engineers, and politics. The politicians—I don't say politicians in a negative way, and people that establish rules, regulations, and policies for the nation, you know? I think that's the part that has been lacking a little bit in terms of: who do they represent do they represent? The big interest or do they represent the nation's interest? And I'm a little concerned about that. So I wouldn't mind some of my students ending up in policy. In fact, I have a couple, I have at least two students that went into policymaking, and I really think it's a great thing to do.

Julie Cohn ([58:08](#)):

Thank you very much for joining us.

Fernando Alvarado ([58:12](#)):

No problem.

[End of second interview]