

**Algorithms & Power Systems Architecture:
Using Historical Analysis to Envision a Sustainable Future
Oral History Project**

Interviewee: Kirkham Harold

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Interviewer(s): Julie Cohn, Daniel Molzahn, Jess Slater, Babak Taheri, Chris Stone

Transcriber: Temi

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Abstract: Harold Kirkham, Ph.D., describes his educational background and professional work in power systems engineering. He reflects on the hands-on experiences he had as an indentured apprentice at Midlands Electricity Board, calling it “an amazing background.” He recalls applying to work in the US and landing at the Edison Electric Institute office in Philadelphia to work on DC transmission issues related to the Northwest Southwest Pacific Intertie project. He describes some of the history of HVDC. He reflects on current challenges facing professors in power systems engineering. He talks about his long-standing interest in measurement. He shares an anecdote about seeing waveform distortion following investigation at a distribution substation. He explains that he was drawn to power systems engineering initially because he hoped to bring clean energy to households in Birmingham that did not yet have electricity in the mid-1960s. Dr. Kirkham discusses the challenge of mastering electric field theory, which he put to use at the Jet Propulsion Laboratory (JPL) developing a device to measure electric fields. He explains the difficulty of measuring electric fields around a direct current (DC) line. He

notes that his instrument was used in multiple conditions. He discusses the range of projects he undertook during thirty years at JPL. He talks about his interest in measurement and the difference between measurement of physical phenomena in an analog world and the symbolic representation of measurement in the digital world. He discusses the challenges this will pose for power systems engineers going forward. Dr. Kirkham explains the difficulty of defining the quantities measured, other than voltage and current, on power systems. He offers the definition of reactive power as a case in point. He describes his soon-to-be published book on this topic [*Measuring the Electric Grid: Mysteries Explained*]. As an example, he explains that understanding the tripping behavior of inverter-based-resources will require more timely and better data acquisition, which in turn will rely on better understanding of what is being measured and recorded. He talks about limitations in electrical engineering curriculum. He discusses collaboration between engineers and scientists at JPL. He closes with advice to students to get practical experience, get “their hands dirty,” as part of their education.

Note regarding Transcript and Timestamps:

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

Transcript:

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

This is Julie Cohn. I'm conducting an interview with Harold Kirkham at July 23rd, 2024, at the Seattle Convention Center in Seattle, Washington. Several other people are here with me, including Daniel Molzhan via Zoom, Babak Taheri, Jess Slater, and Chris Stone, all of whom may have questions to ask during the course of the interview. During today's interview, we're especially interested in your early work on power systems, and then, how it later carried forward to your current interests in measurement. But we'd also be interested in learning more about your personal background. So we'll begin with some introductory questions and general information about you. Could you please for the, for us, describe your educational background and your professional positions in the field of power?

Harold Kirkham ([00:00:54](#)):

I was born in England during World War II, and I have no memory of World War II except what I was told by my parents. My first memories of any education were in the school where the teachers came over and put the cigarette on the side. And things have changed. I was educated at a place called King Edwards Grammar School in Birmingham, and went from there to work for the local power company, the Midlands Electricity Board, it was at the time. And they had me for five years as what's called an "indentured apprentice." And when you're coming outta high school, five years seems like a life sentence really, but I guess you can manage it. An indentured apprentice is paid, but has to do what the owner, as it was, says. It turns out what they were doing was training me, and others like me, to be their engineering staff of the future and their managers of the future.

Harold Kirkham ([00:02:02](#)):

So we got exposed to the entire background of the utility. We dug holes with the guys digging holes. We dug holes for the poles that go in there, one hole per pole, per man, per day. This was before it was completely automated. And I climbed 40-foot wooden poles with spikes on my shoes, and a belt, and did the thing that you do leaning back, working on the line. Never worked on a live overhead line, but worked on the live underground lines. They taught you how to plumb the sheaths together, which is very handy if you want to do plumbing at home. You know how to handle a hot lead. They taught you to be an electrician and they taught you to be an engineer. And they let you crawl all over a generating station and ask questions and they let you operate the generators. It was an amazing background. And that ended with my master's degree, my bachelor's and my master's. And a couple of years later, I immigrated to the US because England was going through a bad time. The jobs were not particularly plentiful. Things would've been so different. If I just had a job and stayed, we would not be here today, that's for sure.

Julie Cohn ([00:03:29](#)):

To where did you emigrate?

Harold Kirkham ([00:03:31](#)):

Philadelphia. Because I applied for a job in California and the job that, the application that I wrote, I just wrote to this guy in, out of the blue, at Pacific Gas & Electric. I knew Pacific Gas & Electric was where I wanted to go. I've never been there, really. But that's where I wanted to go because a guy that I met when I was doing my masters was from the Bay Area. And it was clear he was a very modest, very

retiring guy, but it was very clear the only place worth living was the Bay Area. So I thought, well, let's try. And it happens that the chief engineer, who's the guy I picked from the phone book, basically, to write to, knew somebody who knew somebody who had an opening in Philadelphia that matched exactly my background. So: "would you work on this project? It's only going to last at least a year, maybe two, but it's got a finite end. It's research and high voltage DC and you have high voltage DC in your background already." So nobody did in the US at that point. So that's what got me a green card before I even left England. Think of that. Doesn't happen these days. And they got me a deferment from the military because Vietnam was going on. So that was my first job in the US.

Julie Cohn ([00:05:04](#)):

And which company was that?

Harold Kirkham ([00:05:05](#)):

That the company was Edison Electric Institute.

Julie Cohn ([00:05:07](#)):

Oh, the Institute.

Harold Kirkham ([00:05:08](#)):

Out of New York. Seven 53rd Avenue, if I remember right. It used to be,

Julie Cohn ([00:05:16](#)):

But the project was in Philadelphia.

Harold Kirkham ([00:05:18](#)):

The project was in Philadelphia. The manager was from Philadelphia. But my introduction to it was from a guy in California who knew a guy in New York. So a lot of this is who you know. My first boss was John Dougherty, a great tall, I call him an Irishman. He was a Philadelphian. His father was Irish. His father couldn't make up his mind whether he wanted to be in New York or in Dublin, and he would alternate between the two. He would take the New York Times when he was in Dublin, and finally he couldn't stand it anymore. He came back and he'd take the Dublin Times when he was in New York. So that job

lasted a year and a half. I was married. I'd got married in England before I came over, and that gave us a chance to review: do we want to stay here doing this sort of stuff, or do we want to go back to England? Stay here. And that's what we did.

Julie Cohn ([00:06:17](#)):

Did you continue working on high voltage DC problems after that?

Harold Kirkham ([00:06:21](#)):

Yes. I was very fortunate. I had come across a guy called Cliff Mosher who was a professor at Drexel. Now, the place I was at was on the north side of Walnut Street in Philadelphia, 32nd Street. And Drexel was on the north side of Chestnut, which is one block North. And so he persuaded me to go do a PhD. The whole time I was at Edison Electric, I had a parking spot on the University of Pennsylvania patch where it was, and I knew the parking attendant, so I just kept parking there and he knew me, waved at me. And I walked across the block to my office at Drexel. That went on for three years. And I got a PhD and never paid for parking.

Harold Kirkham ([00:07:16](#)):

And the PhD was in continuation of the high voltage DC work. I was interested in controlling the operation of the DC system, so as to stabilize the AC system underlying it. The real truth—and you probably haven't heard this from anybody you've spoken to—the real truth about the Edison Electric project was, somebody had told the private utilities—Edison Electric was the investor-owned utilities', if you like, "front." As you know, if there'd be one person to talk to, it would be them. And somebody told them that, did you know the government is going to impose a DC line on you on the West coast? To which the reaction was, "can't work. Nobody's ever done that.

Harold Kirkham ([00:08:10](#)):

We found this project prove it won't work." I think that was what they told me. But you give a challenge like that to a bunch of nerd engineers, and we were, we don't not make it work. We make it work better. So it turns out that if you look at the operation of the AC power system and you tweak it right by the controllability of the DC system, you can actually make it more stable, able to carry more power, able to react better in the event of a fault. And those sorts of things were already well in place by the time I got there. And that did carry on into the future. I did a little bit of it at Drexel. I extended that work. And I

used both the model that they had in—over the street—in University of Pennsylvania and I made my own converter. And of all the PhD theses that I've looked at, there have been several. This wasn't particularly interesting what I thought, even though it was mine. Enough, what can you say? It was good enough.

Julie Cohn ([00:09:16](#)):

The best dissertation is a completed dissertation. So that must have been at the beginning of work on the Northwest Southwest tie?

Harold Kirkham ([00:09:29](#)):

The Pacific Intertie. Yes. Which was honchoed by an Indian guy, name of [Narain] Hingorani, who came out of England, who was part of the small DC community. I later worked at the Jet Propulsion Lab under some people who were interested in HVDC, and they pulled together a worldwide meeting, all the people who knew anything in their category of HVDC. And they were stunned to find that I was one of them. Because I wasn't at that time working on HVDC.

Julie Cohn ([00:10:02](#)):

Well, primarily the work was being done in Sweden, correct?

Harold Kirkham ([00:10:06](#)):

It originally was, yes.

Julie Cohn ([00:10:08](#)):

Yes. But was it the case that the HVDC lines developed in Europe were not linking AC systems?

Harold Kirkham ([00:10:16](#)):

That's right. They were not. The first HVDC system was built for Berlin before World War II. It was almost unknown, and it was stolen by the Russians during World War II. And at the end of World War II, all the equipment out of Berlin was now in Russia. And so the first commissioned, publicly known, DC line was German, operated in Russia. But that was essentially the same stuff that was going on in Sweden. And those were all connections between separate AC power systems. And interestingly, just to come right up

to date, there are new HVDC lines under the Baltic supporting the Baltic countries, which are very soon going to disconnect from the 330 KV system operated by Russia. So, <makes noise> Russia. .

Jess Slater ([00:11:16](#)):

Dan, do you have any questions?

Daniel Molzahn ([00:11:21](#)):

Yeah, actually, this is a really interesting story. It's nice to learn a little bit more about the origination of HVDC. So what was the motivating factor behind some of these early HVDC installations? What—was it monetary or ,you had mentioned the government might be trying to push HVDC at the time, and you were told to prove it wrong or prove it doesn't work. Why was there a push for it at the time?

Harold Kirkham ([00:11:48](#)):

I think it started with Swedes as a way to create a new market specifically to interconnect separate AC systems. As Julie has probably serious knowledge through her DNA, you cannot arbitrarily connect AC systems together. And if you do it wrong, they tend to go unstable and demonstrate interesting failure modes, which is not what you want to do. But if there's a DC connection going AC to DC and then you run the wire at DC and then go DC to AC, it doesn't matter what the relationship is between these two AC systems, the interline underlying DC connection controls itself. So if one of these goes down, doesn't matter, they're completely independent in the way they operate. And the first line put in by the Swedes was to a small island, Gotland, off their coast. I think it was not very far from the coast. And I think they could have had an AC connection to it, but they didn't. So they put in this DC line instead and that let them shut down the local diesel generator, whatever.

Harold Kirkham ([00:13:01](#)):

So that's sort of the background of why, and it went from being that to being more: "let's beef up the AC system by putting a DC one in parallel after." I won't say because of our work, but it certainly—there were people doing that. Were aware of our work. And if you look at what is going on now, it's sort of gone back. The Chinese version of high voltage DC is: "our AC system's got too big. We will split it up. We will interconnect the regions with DC." So it's an interesting sort of evolution of what's going on.

Daniel Molzahn ([00:13:38](#)):

And these were all with current source converters at the time, so it was one-directional flows and primarily, is that the right technology era for this?

Harold Kirkham ([00:13:47](#)):

That's exactly right. In the early days, it was all current source converters, one direction. And that was considered a problem when they put an interconnection between England and France, which were different frequency systems, or at least not connected systems. There was a religion that said, "You should never reverse the polarity of the voltage on a cable." So to overcome that, when they wanted to reverse the power flow, they had to switch cables. So that always the positive one was carrying current in some particular direction from where it was connected. But they've connected it different ways. If the power is going from England to France, do this <gestures>; otherwise switch, and you do this, because of this religious belief that the cable would fail if you ever reversed its voltage. I don't know that there's any experimental evidence for that, but they spend a lot of money to do that. And they don't do it anymore.

Julie Cohn ([00:14:48](#)):

When did they stop ? Do you know?

Harold Kirkham ([00:14:51](#)):

Probably right after they found out how expensive it was.

Julie Cohn ([00:14:57](#)):

Interesting. Were you able to persuade the utilities, through the Edison Electric Institute or other venues, that in fact this HVDC line was not going to be the end of the world and would be beneficial for them to participate in?

Harold Kirkham ([00:15:15](#)):

I claim no thing involved. They knew. It was clear. People were becoming aware of the benefits of DC and the community of DC people soon blossomed beyond where I knew most of them. When I moved away from my job on the east coast, finally, to California, I knew the people in the Sylmar Converter Station. I don't anymore; it's—the world has changed.

Julie Cohn ([00:15:48](#)):

More questions, Dan?

Daniel Molzahn ([00:15:54](#)):

No, I think that—that's been very interesting, but I don't have any immediate other questions.

Jess Slater ([00:15:59](#)):

I have one question that takes us a little bit out of what we've been talking about. I read your PAC interview and you had mentioned about this gap in application with certain research. And so I was curious, why do you think during that time there was a gap between academic research and practical applications in power systems?

Harold Kirkham ([00:16:20](#)):

Did I say that?

Jess Slater ([00:16:21](#)):

You said something along those lines, yes, that there—that people were publishing things and that it may not have had applications. But if you don't want to answer that question, we can just scratch it.

Harold Kirkham ([00:16:30](#)):

Well, I'm always willing to venture an opinion. My thought about academic—academia—is these days what I hear is mostly secondhand. But a lot of the academic people I talk to, the profession side, the professors and so on, are quite disappointed in what they're getting from the students. It's not to do with research, it's to do with this fundamental need to have in your mind, some kind of a sense of what's going on when you pick up this, that, or the other instrument, that they seem to lack and they don't understand. He's one of them—says they don't understand that the world is actually an analog thing, because everything's truly digital. No.

Jess Slater ([00:17:20](#)):

How do you think, why do you think there has been this change?

Harold Kirkham ([00:17:26](#)):

I think in the end it's because there are so many, such branching of the technologies and the information and so on, that we have to have to form a certain mindset. There's just too much. It's, in a way, it's sort of a low-level siloing of what you think. And the book that I've most recently written, that's going to go to Wiley next Monday or Tuesday, gets at that. There's a thing called the Instrumentation and Measurement Society. They are approximately 10 times smaller than the Power Engineering, or Power and Energy Society, about 10 to one. And they have to deal with measurements that treat the octane of fuel. They have to deal with the diameter of walls. The measurement world is everywhere and it almost isn't in the electric power system. And I tried to interest the IMS in getting involved with me, in getting the word out about what measurement was about and how it works and what it does.

Harold Kirkham ([00:18:47](#)):

Because in the electric power system, if you don't have a good measurement, you don't know anything. And the fact of the matter is, you didn't realize this, but for the last hundred years, you've been almost devoid of really good measurements. And I don't mean another decimal place on that reader, meaning that a reading that has physical interpretation, something you can hang your hat on with trust. We haven't been there. And that needs to be taught. And IMS said, "Yeah, that's a good idea. Let's talk about that next year when we all get to Kuala Lumpur." "No, I'm not going to Kuala Lumpur." I had already flown all the way to Ottawa just to have this conversation, so I decided at that point that book had to be written.

Jess Slater ([00:19:35](#)):

And you mentioned that right now that these things seem to be taught, if say, for example, you were to be creating a curriculum for students, or are there certain aspects, technical aspects that you think should be included within curriculums?

Harold Kirkham ([00:19:49](#)):

Yes, but the problem is the curriculum is already full enough and dad doesn't want to pay for another year. And I don't have a solution to that. That's a real problem. A first degree takes, in most places, I think, it's four years these days. And you start loading up the curriculum, you're going to need another year. And I did that for my son, but that's because he's a pain in the ass. But he's my son as well, so I'm sort of obliged. But for most people: get your degree in four years and get out and earn some money for yourself, and I don't how to deal with that. It was, I think, historically that you were training people to be

employable. Now I think it's more you're training people to be employable in a particular slot and that reduces the breadth of what is needed to fill that job in that slot. I'm not sure that's a good thing, but I'm not sure I can do anything about it.

Julie Cohn ([00:20:59](#)):

It sounds like your early education was different in kind from the way almost any engineer is now educated.

Harold Kirkham ([00:21:09](#)):

I think so.

Julie Cohn ([00:21:10](#)):

And I'm guessing that the utility you worked for was not the only one that had a training program like that. Is that correct?

Harold Kirkham ([00:21:20](#)):

No, there weren't very many around. They were, they were rare.

Julie Cohn ([00:21:24](#)):

They were rare.

Harold Kirkham ([00:21:24](#)):

But I went to a school that made me learn Latin and French. I picked up German from my brother and you end up getting out of this with all sorts of things you don't need: "I'm going to be an engineer, I don't need that." Well, turns out that's not quite true because later in life you might actually need some of that stuff. The Latin. But the French has proved invaluable. So yeah, most people don't get to do that in high school.

Julie Cohn ([00:21:53](#)):

But I was thinking even more specifically of your experiences, like physically involved in erecting power poles. Checking lines, that sort of thing.

Harold Kirkham ([00:22:07](#)):

I think their philosophy was: "you are going to be their boss or their manager depending on what level you're at. And you need to understand what it is you're asking them to do. And if necessary, you can show 'em what to do and we want to train you for that."

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

Do you think that's another experience that's missing for people going into, not necessarily staying in the academy, but going into work in the private sector, in the manufacturing facilities or for the utilities or even for a system operator?

Harold Kirkham ([00:22:39](#)):

I haven't come across anybody doing anything like this today. Years ago, GE had a program like that. They would bring you in and they would run you through all their operations. But I don't know that anybody's doing it today. I have found it an absolutely wonderful background. And I know this is a fuse. I have—there's a friend of mine up at P&L who was the manager of somebody doing distribution work and I brought a 60-amp fuse in and he had no idea what it was. Oh God. How can this be?

Jess Slater ([00:23:18](#)):

Dan, do you have any questions?

Daniel Molzahn ([00:23:20](#)):

Well may maybe to follow up on that quickly. Do you have any anecdotes or examples of how that background and sort of very practical settings has translated into your research work or into the research contributions you've made? Like have you taken pieces of that and used it in, kind of, any stories about how you use that subsequently?

Harold Kirkham ([00:23:48](#)):

Yes, undoubtedly. I'll give one example. A project that I did when I was, I think doing my Masters, might have been undergraduate, I'm not sure. But back then in the English university, I was given a project to solve how to make a measurement of, from one place, whether there was any other substation around here that's connected to it. As part of that, I had to investigate the current in a busbar in a distribution

substation. Fine. The project worked fine and everything was happy. But one is stunned by the horrible distortion on this waveform. And that has always stuck with me. And this is a planet full, and a community full, of people who are convinced that this sine wave is what we're dealing with. And boys and girls, it is not, it is so far not, you really need to pay attention. So that goes back to the days of getting your hands dirty and going into a substation and doing it.

Julie Cohn ([00:24:54](#)):

So for the viewers down the line who are not technical, can you describe what one would've expected to see and what you actually saw?

Harold Kirkham ([00:25:05](#)):

One would've expected to see a very nice, everybody in this business does this. <gestures to illustrate> It's a beautiful thing. It's in my book. It goes along with this, <gestures to illustrate> which is the international symbol for a spiral staircase. People have these two ideas that these things are, this is what the world is like. And in fact, the current that I was looking at that particular night was like this, <gestures to illustrate> and then like this. <Makes noise and gestures to illustrate> Nothing like this lovely, beautiful, curvy, wavy thing. I have no idea what was causing it. It was pretty horrible.

Daniel Molzahn ([00:25:47](#)):

Interesting. So did—you do you know where the, so did you ever find out where the harmonics were coming from? Or, I presume, harmonics were coming from?

Harold Kirkham ([00:25:54](#)):

No, I didn't. And I think the reason is that it was so routine to see this, that nobody gave it diddly anymore and you just lived with it and you didn't track it down; this was long enough ago. This was not because of the solid-state motor control on a whole lot of washing machines. This is ordinary stuff in the days before solid-state power systems.

Babak Taheri ([00:26:21](#)):

So was it causing transformers a problem at that time?

Harold Kirkham ([00:26:25](#)):

Well, you wonder if there was a transformer somewhere getting saturated, causing this, but I, nobody really looked at it. And some years later, a guy called Nando Ochoa in Manchester did a big study of the distortion and stuff by instrumenting part of the distribution system in Manchester. And he found some similarly horrible results. There's a thing called total harmonic distortion, which sounds like it ought to be somewhere like one or two percent. He was finding numbers above a hundred percent. There's a way of defining it, the number that can be bigger than a hundred percent, but a hundred percent distortion is a case of: really? But the answer yes and is all over the Manchester system just as it was back when I was there, all over the British, the Birmingham system, I suppose. It's just nobody knew because nobody never instrumented it before.

Julie Cohn ([00:27:21](#)):

Was it something that was affecting system stability?

Harold Kirkham ([00:27:24](#)):

No, because the distribution system never goes unstable. Ah, it's point to point. And if you, if you cut a wire, it's dead. Right. And then there you go.

Julie Cohn ([00:27:34](#)):

But it could have presumably affected the customer using the electricity?

Harold Kirkham ([00:27:40](#)):

Oh, I would think so, yeah.

Julie Cohn ([00:27:41](#)):

Yeah. But there, people weren't, there's no record of a big stack of complaints on the customer service desk at the utility?

Harold Kirkham ([00:27:49](#)):

Not that I'm aware of. The thing that primarily distorts is the current, and the thing that you primarily care about when you are a customer is the voltage. And if the voltage isn't that badly distorted, even if

it's more distorted when you're finished with it than it was when you got it, that's too bad. The utility will fix that at some point.

Julie Cohn ([00:28:11](#)):

Interesting.

Jess Slater ([00:28:14](#)):

Chris, you have a question?

Chris Stone ([00:28:15](#)):

Yeah. So as someone who has recently graduated engineering program, granted it was a very, definitely a very theoretical program. The opportunities for practical application largely had to be done through my own pursuit of finding research opportunities and finding internships outside of what the institution's curriculum itself offered. And a large part of that, I believe is, as you mentioned, there's only so much time in the courses, especially with something like an ABET accreditation that is expected about engineering programs. Like you can only fit in so many courses while still getting ABET accreditation. But going sort of back to your discussions with your professor peers, I'm curious what, on the other hand, what are some things that they're finding fascinating or some lessons learned that they're finding out of working with this newer generation of students? And what, where are their thirst for learning seeming to come from?

Harold Kirkham ([00:29:14](#)):

Say that last bit again. I missed it.

Chris Stone ([00:29:16](#)):

Where does their thirst for learning seem to be coming from, where their interests are flourishing more?

Harold Kirkham ([00:29:23](#)):

I think you born with it, don't you?

Jess Slater ([00:29:26](#)):

Or if anything, can I take from that question?

Chris Stone ([00:29:28](#)):

Yeah.

Jess Slater ([00:29:28](#)):

What were the interests during your schooling? I know that for a lot of people that the 1965 Blackout or some other events caused what they cared about to change. And I'm curious, are there any particular events, whether it be governmental policies or anything else going on that affected the way that you were inspired to continue your work?

Harold Kirkham ([00:29:51](#)):

It's going to be hard to believe, but I thought when I got a job with the power company, I'd be saving the world by bringing clean energy to it. And I remember wiring a house in the middle of Birmingham, a Victorian-era house that when I was there, hadn't had electricity. And this is 1965 or so, no more—bit more like '7 or '8. But no electricity at that point in the middle of Birmingham. Goodness. And I thought that was great. You know, that: here I am, I'm running new wires. That was when I was learning to be an electrician. I thought this was bringing good clean energy to these poor souls. They bulldozed the houses down a few years later. It turns out for the university that I was, that just right across the road. But I was motivated as much as anything by the idea of doing good and bringing clean power to people. My personal interest, from a very early day, was in electronics. I collected radio, fixed radios from the neighbors, and now I collect old radios. Which got me into the measurement side of heavy power rather than the power side of heavy power, mainly because, hey, you could move around with electronics stuff.

Julie Cohn ([00:31:11](#)):

What were the, what was the top most challenging technical problem you took on during your professional life?

Harold Kirkham ([00:31:26](#)):

I don't think I've had any technical problems. I have some learning problems and stuff I never wanted to do, never thought I'd have to learn and understand. And it turned out I did. And that was electric field theory, which was really put into writing by Maxwell in 1873, the treatise, and then made intelligible by,

oh, what's his name? Heavyside. But it's intelligible only to people with much more intelligence than me. And the first year I took the class in the electric field theory, I managed to fail. So did everybody else in the class. But it's just dismally difficult. It introduces symbols that you have no real idea what it means. And a lot of mathematics seems to me that it's symbol manipulation and if you don't know what the symbols are, you're not going to get it. Right? That was me.

Harold Kirkham ([00:32:33](#)):

So that aspect of my career has always been a bit strange, shall we say—

Julie Cohn ([00:32:38](#)):

Did you ever have to apply it, that theory?

Harold Kirkham ([00:32:41](#)):

Yes, of course. I am now an expert, believe it or not, in the measurement of electric fields. Measurement again, yes. But there was a situation where you probably didn't, you're not aware of this. You walk under a power, high voltage power line, your ears have a 50% chance of falling off or some other disaster will happen to you. This is worse than working under a ladder. Power lines are dodgy. Everybody knew this. They knew that it causes cancer in children and all sorts of stuff. So people started doing research to prove that that wasn't really the case. There was a couple whose name eludes me. They wrote a paper showing a correlation between cancer incidents and the kind of wiring used in the house, which has changed over the years.

Harold Kirkham ([00:33:34](#)):

And they were able, to their satisfaction, to show a relationship. And this started to scare that power system was producing dangerous magnetic fields or electric fields. And that, subsequently that work was discredited because it turns out the correlation between the wiring in the house and a lot of other things about the house was a lot greater than the exposure of the people who were moving around in the house. It might not even be anywhere near the wiring, like we did at the time. But research was done because grants could be obtained. So people all over in this country, in Russia, Australia, were doing research in the biological effects of electric and magnetic fields. And it's not difficult to measure an AC electric field in the air, at the end of a long insulating stick, so you're not disturbing the electric field and get a reading from it.

Harold Kirkham ([00:34:36](#)):

And the first device like that was put together and it was a self-contained device, and it had a meter on the front with a needle that did this. And you could read the scale. It's only about six or eight feet away, 'cause big thing. And you could, oh yeah, it's about 10 KV per meter over there. Of course, it distorted the field, but it could be calibrated so that you were reading what it would've been before you put your instrument in there. There was no equivalent for a field of DC line. And that's what I made at JPL. I introduced that technology, produced that technology, with some of the geniuses that I was lucky enough to work with at JPL. And we made an instrument that measured, was the first instrument I'd ever heard of, to measure the electric field in air without screwing up the electric field that we're trying to measure.

Harold Kirkham ([00:35:30](#)):

And it got borrowed to measure the electric field in a snowstorm, because it turns out the electric field on the snow has an effect on where the avalanche seam is. And who knew that? Well, this guy did. He was a snow bunny and he just wanted to do this because hey, get him out in the snow more often. It was used to measure the field around HVDC insulators in Sweden. And I was flown over there for that. My instrument from JPL went with me. Two of them, one of them broke in transit, but. That was interesting. It was, it was a, a laboratory, oh, several times bigger than this, with a wall in the middle, they built a bushing through it. The thing was 15 meters long, if you can imagine. And they were raining on one side of it and they were blowing wind at it.

Harold Kirkham ([00:36:38](#)):

And there was my meter up there. And when they turned the power on, it was 600,000 volts. And it all worked lovely. And they were able to move the instrument up and down on a platform that they had built. And then the, it was noticed that at some points the instrument had a cheerful blue glow on it. Gone into corona. Still working though. So we got some results that proved a theory that they had had. This was at ASEA, right before it became ABB, and they proved that their theory of what was going wrong with DC insulation was indeed what they thought. It was field intensification, using partial wetting. And my instrument didn't care about wetting. It was a spinning instrument and it just threw the water aside anyway. So yeah, that was kind of fun. And also dust devils, which got me to Mars actually. It didn't get me to Mars, but it theoretically got my instrument to Mars, because it turns out dust devils

have an electric field. And one of the researchers in that business is a guy called Nilton Renno at the University of Michigan. And he called me up out of the blue when I was at JPL. "Are you in town tomorrow?" "Yeah." He says, "You drink beer?" "Yeah, I'm an engineer. Of course I drink beer."

Harold Kirkham ([00:38:05](#)):

"I'll buy you a beer. I want to talk." And he'd read some of the papers that I'd read. He'd been measuring the electric field of dust devils in another way. And he'd come to the conclusion that what I was doing was right and what he was doing wasn't working. And he was right. So I got involved. He was funding me at JPL from a university—that never happens—to join his project in Michigan. And we did, we developed an instrument, developed a better instrument than the one I had. And that was good. That's, he's made several of those and uses them in dust devil work. We made one for Mars. But the particular Mars project was canceled for some reason. Something else happened that went wrong with that and it never got launched. It would've worked. And we're quite sure we know what's going on. He in particular did some good work with several meters stacked up to a height of about 20 feet and proved his theory of where is the electric charge in the dust devil. And the answer is, it's more than a few feet off the ground and less than 20 feet off the ground. But the center of charge is up there, not down there or way up, it's back there. And very interesting.

Jess Slater ([00:39:30](#)):

Dan, do you have any questions?

Daniel Molzahn ([00:39:32](#)):

Well, so I was curious, as you're describing this, can you give a little bit more, I guess, maybe, an intuitive explanation as how—was the measurement device you were building, or that you had, that you had built, or maybe the series of devices you built—how did they, how did they work? What was the—I can imagine that it is harder to measure the DC fields than the AC fields. What was the trick in getting it to work for the DC fields?

Harold Kirkham ([00:39:56](#)):

The AC field, all you have to do, the simplest way to do it is to take two metal electrodes, two conducting electrodes, one here, one here, half a sphere, one pointing up, one pointing down. And you measure the current between them when you insert this into the electric field. Because charges induced on this

surface, charges induced on this surface, you'll get a current, and it's an alternating field. So it's an alternating current and you can get a measurement of that. And you can either put a big meter on there or what we did was we put a fiber optic connection on and brought the data out through fiber. To make the same thing work with DC you have to have motion. And that's, that was the thing that hadn't been recognized by Nilton and his predecessors. If you don't have motion, the field dumps charge on this, the field dumps charge on that, and then it stops because it's done and your reading goes to zero and there's nothing else.

Harold Kirkham ([00:41:00](#)):

So there's several kinds of motion you can have. And we chose rotation of—cylindrical geometry with rotation along the long axis. And my first instruments had fiber optic output. So you put the fiber down the middle of the support pole and you could have two-meter pole or whatever you want, and you have a certain bend as it went, but it was good. And you could measure the field around somebody standing under power. And then we did that, that sort of stuff. So you could see what you do to the electric field, you intensify it at the top, but you shield it at the bottom. Fascinating. If you put a hard hat on, you know what happens? Your hard hat collects a whole lot of charge because your hard hat is an insulator. They make 'em out of plastic. So that works very well.

Harold Kirkham ([00:41:52](#)):

And that's what we did. And the version that Nilton made in Michigan didn't use fiber. It used radio. So he got data out by Bluetooth actually. And our drive system was air propulsion. We wanted the tiny motor. You know what the smallest motor you can get is? A dentist drill motor. So our second small device sounded like a dentist drill. Not in the least pleasant: I'm just going to run this by you. It won't hurt. You can imagine. Whereas here's just a little electric motor going whirrr. So anyway, you have to have motion. We chose rotation. There's a lot of advantages to that over oscillatory motions or flat motions and there you go.

Daniel Molzahn ([00:42:46](#)):

I see. No, that makes sense. Thanks for clarifying.

Harold Kirkham ([00:42:49](#)):

You're welcome. Of course. So HVDC fields.

Julie Cohn ([00:43:00](#)):

So you, you went to the JPL.

Harold Kirkham ([00:43:03](#)):

I went to JPL.

Julie Cohn ([00:43:04](#)):

And how long were you there?

Harold Kirkham ([00:43:05](#)):

I was there 30 years. That's—

Julie Cohn ([00:43:07](#)):

That was your primary place of employment?

Harold Kirkham ([00:43:08](#)):

That's a career. Yeah, I worked there for the DOE mostly, not NASA. But, of course, you get involved in the community of JPL. And it is a wonderful lab. It is, as far as I'm concerned, it's not just because it was there. My experience with other labs is JPL knows how to make this work. You've got the problem of scientists and engineers and you've gotta try and make 'em work together. They don't even dress the same; it's just sad, but true. You can always tell 'em apart from the way they dress. But JPL's made it work and JPL acknowledges the contributions of the scientists and the contributions of the engineers to what they do. They don't do great research; they're not very interested in good research in the engineering side. But they are interested in good science and they're interested in robust systems on the engineering side.

Harold Kirkham ([00:44:13](#)):

And I learned a lot from that. But I was working mainly on the DOE stuff, starting with something that they called DSG—distributed storage and generation. When I went for my job interview, I couldn't stand the weather. I was in Indiana at the time working for American Electric Power. In Indiana the snow was this deep, the first winter I got there and I thought, oh, people exaggerate. And it just got worse and

worse and worse. And the last year, the last winter I was there, we were snowed in the house for a week. So enough. I went to Southern California. But then the job interview, they said, "We are working on DSG." "What's that?" "Dispersed storage and generation." "What's that?" I had no idea. But they knew what they were talking about and they demonstrated to me that they knew how they were going to work the system. So: "did I want to join them?" I'll—I don't know. So I sat on the airplane going home for the interview, and I decided—flying from LA to Chicago, Chicago to South Bend, driving home—it wasn't till I was walking up the path to home what I was going to tell my wife. And I said, "Yeah, I think I'm going to do it."

Harold Kirkham ([00:45:33](#)):

And I never looked back. It was a wonderful place. I was only going to be there five or six years. Right? And then one day I realized I'd been there long enough, I should retire. They kept me busy doing interesting things, for all that time.

Julie Cohn ([00:45:48](#)):

How much of the work there actually was applicable to the power system versus other types of projects that they might have had underway?

Harold Kirkham ([00:45:56](#)):

Well, for the first half, all of it. First half, all of it was DOE-funded work. The last half, a lot less was funded by DOE, but I was still doing power system work either on spacecraft or on the underwater project called Neptune. So I still kept my hand in with the high voltage stuff and the high current stuff. But I was mainly doing some interesting measurement stuff as well at JPL. They used me as a sort of backup sometimes in the electronics. I started out there in the division—they have technical divisions, and then within that there are the subjects for the technical divisions. I started out in the technical division for power systems and control, migrated gradually to the division that does system engineering, and then migrated from there to the Office of Mission Assurance, which is not a technical division, but was doing good solid engineering, where I learned about reliability and calculations for reliability and stuff like that.

Harold Kirkham ([00:47:13](#)):

And I left them, because at the time there was something called the smart grid being talked about, only talked about, but people like Microsoft were running ads on the television. And the smart grid was the

outcome of this DSG work I've been doing before. That led to what we now call the smart grid. And did I contribute in the DSG work? Undoubtedly. There are a whole lot of people who did, not just at JPL, I tell you. Oak Ridge was much bigger for DOE than we were, but we had a good effort going and we did some good stuff. It tended, for some strange reason, to lead towards measurement after I took over.

Jess Slater ([00:48:05](#)):

Dan, do you have any technical questions to address?

Daniel Molzahn ([00:48:08](#)):

Well, could you expand on that a bit more? So as you were starting to get involved in this kind of, maybe, terminology transition—I don't know—to thinking about smart grids, how did measurement fit into that? You kind of just finished your thought on this. I'm curious if you could expand with where you're just going.

Harold Kirkham ([00:48:28](#)):

How does, how does measurement fit into smart grid?

Daniel Molzahn ([00:48:31](#)):

Yeah, like, obviously we have to measure things right in to have smarter systems.

Harold Kirkham ([00:48:36](#)):

Yes, it's obvious we have to measure things.

Daniel Molzahn ([00:48:38](#)):

Well, what does that look like?

Harold Kirkham ([00:48:40](#)):

Well, people haven't really understood that, and that's really what I think my life contribution is going to be, is from this point on. People haven't really understood that while we have hearing that detects sound pressure and decodes it in some little gray cells. And the same with isofrequency radiation in the electromagnetic spectrum, we are not able to directly sense anything on the electric power system,

except at considerable hazard to oneself. And so anything you know is because you've made a measurement of it. And as I see the problem now, there's only two things you can measure on the power system. It's the voltage and the current. And from this you dream up a whole bunch of other things. You conceptualize these other things because that's how you make a measurement, is you begin with a concept. All the things you measure begin with the concept, and you say this in a room full of power engineers and they begin to start checking their email, because they don't know what you're talking about. But it's a fact. Everything you know about the power system comes from a measurement. And when your grid gets smart, it's controlling more. And that has to be automated and that's why it's smart. It has to be automated. There's too much of it for people to be managing it, thank goodness it's all software. So there's never anything going to go wrong there. Right.

Harold Kirkham ([00:50:18](#)):

That reminds me of a line from—one of the JPL guys one day was giving a talk about a particular spacecraft that was about to be launched to go to Mars. And he said, "It's just like a computer, really, with some peculiar accessories, shall we say—?" Yeah, oh yeah, right. But what we are doing today is using computers to solve all of the problems. And that has, in my view, has revealed something that has not been understood until now. A few years ago, a guy at NIST said to me, something about the digital revolution in measurements, "I've got the digital revolutionary measurements." I'd not heard that term and the term stuck in the mind. And so, I thought about it: what does that mean? What—how do I interpret that? And the digital revolutionary measurements begins with something that I'm not sure that even he understood.

Harold Kirkham ([00:51:26](#)):

I have this thing that I do. I go into a mode of just thinking. I'm not doing anything. I'm just going to sit here and think. My wife can tell when I'm doing it. She's come to recognize what whatever body statue happens. But I can do it when I drive, and I had a house I was repairing; it was a three-and-a-half-hour drive from home. It was three and a half hours of sitting behind a wheel on auto drive—think about this for a while; gives you a lot of time to think. And in the end when you, when you get to see a digital measurement, you realize the very beginning is analog. Here comes a signal up and down or in and out, whatever it is. And then you have an A to D converter. And out of the A to D converter comes a symbol, a symbol might be a one or it might be a zero.

Harold Kirkham ([00:52:19](#)):

And they come out of a stream of symbols one and zero. Now they're represented by a voltage, which is up or down, but they're symbols. So the A to D converter has taken everything from the physical world and converted it into a string of symbols. You are now in the conceptual world. That was not obvious when you made a measurement with an analog meter with a pointer. It is unavoidable now. And what do you do in the conceptual world? You operate with algorithms on this data. That's making a measurement. And that I think is not well understood by most of our community. And those algorithms had better be the right ones. You better get sure that they're doing what you think they're doing, because they are where you implement the concept that you had in mind when you said, "I want to measure the—", whatever you want to measure: power, the reactive power. And people have the wrong idea about these things. People think power is somehow like cheese and you can cut it up and call that piece real power and that piece reactive power. No, it doesn't work that way. It's an algorithm. You've given it a name. And if you happen to put the word power on it, it doesn't mean it's anything to do with power. It's because you haven't got a clue about naming.

Jess Slater ([00:53:52](#)):

Dan, do you have any more questions?

Daniel Molzahn ([00:53:54](#)):

Well, to kind of continue this point a little bit. How do you—one thing that comes to mind with this is kind of the relationship that we have in, say, the information technology, the computer sciences, we're frequently building abstractions on top of abstractions in that setting. And you could argue that you have the hardware layer and then you have application layers. You have all these different layers and each layer just needs to understand what's the abstraction of the level below it enough to sort of interface with that level to do its job correctly. And so I wonder if there's—is there an analogy, like does that analogy kind of make sense in this context that you could say, I'm working on the algorithm piece and as long as I understand how that interfaces with the measurements, I don't need to understand all the details of the measurements. And as long as the measurement person understands what the measurements are doing, they can pass that information sort of up the chain. It sounds like you're advocating for not doing that, or maybe I am misunderstanding.

Harold Kirkham ([00:55:06](#)):

Oh, I can be misunderstood partly because I've spent a lot of time thinking about some of these things and not everybody has. But yes, it does relate in a way to the stack. But if you think of it the way I think of it, the physical layer, yeah, there's a physical layer. The physical layer is either a voltage or a current. You go into the A to D and you come out right away in a conceptual domain. You have left that world behind. All you know about that world is what your A to D converter told you. And possibly the time which you decide to say, "This is time equals zero," or "This is time equals UTC noon in Wales or something." But that's all you know. Now you're in the world of conceptual stuff that you have in a symbolic form.

Harold Kirkham ([00:55:59](#)):

Now you can make the symbolic form more meaningful by getting it out of ones and zeros and interpreting it as a voltage. And now you need to have an algorithm to put the scale factors together, what was the transformer ratio over there and so on. But that's the digital revolution. If you get it wrong, it's just a software upgrade to get it right. We hope. You were doing all of the things in the analog world before the digital, your meter that gave you a reading for voltage, for example, developed magnetic fields. It had a magnet, maybe a fixed magnet and a magnetic field was generated by a wire inserted into a piece of iron in that magnet. And a torque was developed between the static magnet field and the one you were going to move, that moved the pointer. This is all analog, this is all physical.

Harold Kirkham ([00:56:56](#)):

But the moment you read that pointer, you had the idea in here what it was. Now you are in the conceptual world. And if you wrote it down, you're still in the conceptual world because you've gone through that step of saying, "I interpret this to mean two volts." So now you've got two volts, and is that two volts? A philosopher by the name of Eran Tal would say, "You can begin the statement that that is two volts. If you precede it by saying, assuming that my assumptions about the way this measurement was done were true, then that is what it is." And we don't do that. We should have that carefully in mind. We really should say, "If the assumptions I make are valid, this is what that is." Because what you find when you solve whatever's in your conceptual domain is still only a conceptual thing. Interesting. Bizarre. People get a little confused about this in this world, and that I think is my contribution is, you're going to get over this, we're going to have to live with this, guys. Doesn't happen overnight.

Daniel Molzahn ([00:58:17](#)):

So is a piece of this of what you're advocating for is being able to understand the limitations of the measurement systems that we have? Is that—is—am I interpreting what you're saying correctly?

Harold Kirkham ([00:58:28](#)):

That's one part of it, yes. There the measurement systems that we have evolved, as analog things, over the last 100 or so years, 150 years maybe. And back in the very early days, it was important for the student to know how to make the instrument. That became a little impractical. At about the turn of the 19th to the 20th century, there was considerable growing interest in the electric power system. There wasn't much of a power system, but people were interested in it. And one of the teachers in that world, in England, was a developer of the direct reading meter. So whereas you would ordinarily get a current or whatever you're measuring on your meter, and you read the scale and it would say 8.6 and you would go here and look up on the chart what 8.6 actually meant and that then you had your number. So we said, "Well, why don't we just write the numbers down on the scale?" It seems so obvious, but it wasn't. And then there came a time when the world of science said, "If we do that, the student will never understand what's going on."

Harold Kirkham ([00:59:51](#)):

Turns out they were probably right and it's just taken this long for us to figure that out. But if you plug in a digital meter, plug it into the wall thing and it says, "124 volts," you think that's 124 volts, but you don't know what's going on to produce that and you take it for granted. And that's the problem. You get a reading and you take it for granted.

Daniel Molzahn ([01:00:19](#)):

Do you have examples of, or anecdotes of, cases where engineered systems had failures or had unexpected behavior because of these measurements issues?

Harold Kirkham ([01:00:33](#)):

There is a list of five or six of them in a presentation I gave a couple of days ago. This is where large, what they call these days, inverter-based resources tripped offline and, NERC at least thinks they shouldn't have. And I could think of several reasons why they do that. One of them I only thought of today. And that's a management question, not a technical question. But the reason that these things trip off, to a technical person is a bit of a mystery. The first one that I heard of happened in August of 2016 when

there was a fire in southern California in the vicinity of a trailhead called Blue Cut. And so it's called the Blue Cut Fire. You have to name fires; otherwise people don't know what you're talking about. This is the Blue Cut Fire and smoke goes in the air. Smoke is a pretty good conductor. And so it caused short circuits randomly throughout a day or more on the high voltage lines in Southern California. And sometimes when a line would short circuit, it takes usually a couple of cycles for the protection to clear it and then it goes back to operation.

Harold Kirkham ([01:02:02](#)):

Some of these events coincided exactly in time with tripping of very large solar generators, hundreds of miles away. That shouldn't be. And that came to my attention when a guy who at the time was head of the team at NERC that does sequence of events studies said, "Harold, do you know anything about converters?" "Well, I know a little bit about converters. What's your problem?" And he told me about this. And I go, "Wow, that's just weird." I still don't know exactly why, but I'm beginning to understand why nobody knows, because frankly, you can't persuade management to spend the money to find out. But you've never heard of that sort of thing before. Right. the deal is they had one in England, I've heard that they've had this happen in the Netherlands and in Denmark. In England, there was a lightning strike just north of London, just south of a generating station.

Harold Kirkham ([01:03:11](#)):

Then I don't know what the lightning strike looks like, but it progressed as far as the generating station and the generator tripped offline. Fine. And way up north of England, almost in Scotland, out here is a connection to the Hornsea Wind Farm out in the North Sea, that decided to trip off as well at the same instant. I don't know why. I've got several ideas as a technical guy. But this is a repeating problem and it's caused by: the assumptions I made when I made the experiment, were not valid at that time. Whatever's going on, something goes invalidating my assumptions.

Daniel Molzahn ([01:03:58](#)):

And so then presumably that's something—is the measurements that you're getting at is. There was an assumption about how the measurements were being taken or what the measurements meant that was not valid?

Harold Kirkham ([01:04:11](#)):

Yes.

Daniel Molzahn ([01:04:11](#)):

Is that—that's what you're getting at here, right? Is that right?

Harold Kirkham ([01:04:13](#)):

Yes. Something got into the control system or the protection system at Hornsea, or at the, in vicinity of Blue Cut, or any of at least a dozen of these things that are known. Something got in there, some distortion that wasn't anticipated, or some impulse that wasn't anticipated. And whatever the protection system or the control system expected was no longer true. If it's the control system seeing this, the control system gives a notice of protection system and says, "We need to get outta here because I don't understand this." If it's a protection system that upsets in the first place, the only thing they ever do is disconnect. So that's—I think that's—it's an interesting problem for the future, technically. I think it's going to be fascinating.

Daniel Molzahn ([01:05:10](#)):

Maybe one other follow up before, maybe, I should hand it back to Jess for, or Julie. One common theme that we've been seeing pretty frequently through a lot of these interviews has been how we used to do a lot of work on analog simulators of the grid that we'd have. You, you build a physical model of the system and test out your algorithm in this sort of scaled down physical model or analog computer type of device. And we talked with a lot of folks who were saying, well, then we moved to these digital computers to do the analysis. And a lot of concern at the time was that we might lose some of the engineering intuition that went into sort of understanding how the system physically worked.

Daniel Molzahn ([01:05:56](#)):

And then, of course, in many situations the advantages of digital computing sort of dominated the—we brought all of our simulations on digital computers nowadays. So I'm wondering if there's a kind of another analogy here or if you've thoughts on this of, did we lose when we had kind of analog simulators, analog computing devices to do our simulations? Were more of these measurement issues sort of baked in? Or was it still a problem in those, that setting?

Harold Kirkham ([01:06:30](#)):

Well, I think of digital twin as a way to think about these things. I heard about the digital twin or turbine engine, for example. This is a useful idea. The problem is only that, if the assumptions I make about the way I make the measurement aren't true, then your digital twin is going to go off and see the wizard. And that's a problem because a lot of the assumptions we make about the operations power system are that it's in a fairly normal, ordinary sort of state. And every now and then there's a fault that just happens. A tree falls on the line and an airplane flies into a line or whatever it is, a lightning strike causes a flashover. And for the milliseconds after that, the waveforms are nowhere close to what you've been expecting. And we need to find a better way of dealing with that.

Harold Kirkham ([01:07:35](#)):

Ultimately, that's why these resources are tripping out, because the waveform somewhere has gone off the rails and doesn't look the way it was expected to look. And we need to know how to deal with that. One of the problems, I think, is that we are not recording these things when they happen. Why don't we record? Well, they don't happen very often. And the chances of you having a recording process go at the right time at the right place, it's low. It's low if you don't spend the money. And I'm reminded of a thing called FIDVER, fault-induced delayed voltage recovery, which was a, a thing invented in Southern California. And it was discovered that if the subtransmission system had a fault, the voltage would collapse the system. The fault would clear system would come back up, but below the subtransmission was the distribution system, then it wouldn't come back up.

Harold Kirkham ([01:08:35](#)):

And the guys at, I think it was Southern California Edison, figured out what was going on. All the air conditioners have got induction motors, and all these air conditioners are there going and refusing to spin up the speed. So they're pulling reactive power out of the system and holding the voltage down until finally one of 'em gets up to speed and then another, and then after a few seconds or minutes, the voltage comes back up. So how do you prove that? Well, indeed, they blanketed their whole northern area with small data acquisition devices and finally they caught one in the act. And now you can check the box. Now I know what the problem is. But that's what it takes. And as far as I'm aware, nobody's got the right kind of data acquisition going at the, in the right places to solve this big IBR problem.

Harold Kirkham ([01:09:33](#)):

The closest I've seen is, I saw a waveform, from a fault recorder nearby at the Blue Cut. And you could see what was going on—three phases. And obviously two of them joined together some distance from wherever this recorder was, and the problems were associated with the waveforms after that. Because when you join two wires together, the voltage between them instead of being something becomes nothing quickly. So instead of a sine wave, you get a step to zero in the sine wave. And that's not like a sine wave. So somewhere a control system or a measurement system said, "Hmm, trip." And that's okay: everybody lives, the world continues to turn, but NERC gets upset.

Daniel Molzahn ([01:10:29](#)):

Got it. No, this has been really interesting and I appreciate the examples. I don't want to take the full conversation over here too much. If Jess, Julie, or Babak have questions, I'm happy to pass it back to you guys.

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Daniel Molzahn ([01:11:18](#)):

Okay, great. Then maybe my kind of follow on to this is—I think I understand a bit better the perspective you're bringing. And you're kind of advocating for, and with, your book coming out. So, I'm curious, what if you had to summarize the sort of message to power engineers—that the kind of takeaway about the importance of measurements and the role that measurements play and how we should be thinking about this going forward—what's the summary of that or how do we—or if I was explaining this to my students, what's the message that you would want our faculty to be passing on to students in, in this regard?

Harold Kirkham ([01:12:00](#)):

The answer to that is my book. This is—there is no short answer, but the existing community of power engineers is going to struggle to accept validity of what I say. We all, myself included, have somehow in our minds got the idea there is a realness about the things that we deliver as the result of a measurement. That power is a thing, that resistance is a thing, and these are just concepts. And that's not easy to wrap your head around in a satisfactory way to start saying, "Well, I can define this thing better and therefore measure it better." And it has—I think therefore to come only from a student whose mind has not got too much pre-programming in it, shall we say about the reality of what we as engineers

encounter in our lives. I—there is no such thing as reactive power; that's just the name you give to an effect that you can replicate in software.

Harold Kirkham ([01:13:21](#)):

But it's not like you could carve yourself off a piece of power. And in fact, it has some peculiar constraints on it that the sort of power that warms up your toast doesn't have, and people don't know about that. And convincing somebody of that who's been dealing with this stuff their whole life is, that's, I think, not possible. Which is why I'm hoping the book would make its way, at least in part, into the curriculum somehow. And I understand the problem. One of my co-authors, no, two of my co-authors are in fact professors. So one of them I know is already carving out a piece of the curriculum to start to introduce this stuff. The phasor measurement unit should be the best ever measurement made in the power system. It's the first measurement in the power system that is of the kind that is called representational.

Harold Kirkham ([01:14:23](#)):

And it is so damaged by the national international standards for the phasor measurement unit, that I was part of writing. I didn't know this when I was writing those standards. I kept asking them to explain what this was all about and they didn't know. They wouldn't tell me. They didn't tell me. They couldn't. And it's all nonsense. And it's because we haven't figured out what we are trying to measure in the phasor measurement unit. We're trying to measure a phasor; it's a phasor measurement unit. And you ask these people, 99.94% of them will tell you what a phasor is and get it wrong. That's a problem. A guy who was, I would say, dominating the early days of the standard writing for the IEEE standard, left because I replaced him. I was asked to replace him because he's getting old and past it.

Harold Kirkham ([01:15:23](#)):

He dominated that group to the—where they think that what they're measuring in the phasor measurement unit is they are demodulating a 60-cycle carrier. No, this is not FM, this is not a radio, this is a measurement. And because of that thought, that concept, the standard describes an instrument that you can make, and it will totally screw up what it's trying to do. And so it describes how you can get around that, and it's filtering, and it adds a large delay to the measurement. It's not needed. So trying to persuade somebody of that generation—I should say, of my generation—of the truth of what I'm trying to say—this is not religion, this is actually engineering and science, but you ain't going to believe it. I put on a slideshow today that—I said in the middle of this—"I gotta tell you what the problem is exactly in

two slides and you would not believe it"—they don't believe it—"the problem is that the signals you're dealing with are way more complicated than the measurement systems you've got to deal with them. That doesn't tell you how to do it, but it tells you what the problem is."

Daniel Molzahn ([01:16:45](#)):

Thank you. I appreciate it.

Harold Kirkham ([01:16:47](#)):

Does that help?

Daniel Molzahn ([01:16:47](#)):

That sounds a nice summary. Okay. I have taken a lot of time here, so I have pass it over to Julie or Jess, or you had a question.

Babak Taheri ([01:16:58](#)):

Okay. My question, if you can, like, answer, like, shortly—I know there's probably no short answer—but what is the difference in, like, HVDC lines? You talked early and—

Harold Kirkham ([01:17:08](#)):

What is the difference?

Babak Taheri ([01:17:10](#)):

Like HVDC lines that we had, like you had before, early, because right now they are pretty expensive. How was that before?

Harold Kirkham ([01:17:18](#)):

Like, oh, they've always been expensive. For very simple analogy that you, you've gotta pay a certain amount for the terminal equipment and a certain amount for the line. The line costs less than an AC line because it's only got two wires, but the terminal equipment costs more. So the very simplest analysis at some distance, the cheapness of the line will offset the expense of the terminal. So they have tended to be long lines, because they are cheaper, but in fact they operate differently. If you build an AC line that

can transmit, say, two gigawatts and you build a DC line that can transmit two gigawatts, the difference is that the relationship between the two ends of the DC line are set by a control system. You can do what you want more or less. Whereas the AC line is set by physics and the laws of physics don't let you do some things.

Harold Kirkham ([01:18:14](#)):

In fact, they don't let you do anything at all. The laws of physics will still apply to the AC line. And this business of stabilizing the AC system with the DC is because of the controllability of the DC line. You can see it's like a volume control. You can turn it up and down. When we did our work in Philadelphia to understand the stability effect on the, on the AC system, we had a physical model, very large physical model of the western system. A simplified model, but large. Big, big generators—I mean, big generators. And we showed that it worked. And one of the reasons it didn't really go permanently into action in the power system was that it turns out if you start to exercise this control here, it can affect an oscillation mode over there that you weren't aware of.

Harold Kirkham ([01:19:15](#)):

And in our simplified model we didn't see that. But these days this work is being done and there's a guy Dave Schoenwald at Sandia National Lab who has taken that exact problem and solved it so that he can now say for controlling this, "We are aware of this mode here and we know how to deal with the possibility of stimulating a mode that we don't want to stimulate." And that some of the graphs and curves that he gets are very, very reminiscent of the stuff that we saw in Philadelphia. It's a joy to see. It really is. And I'm going to talk to Dave. I was speaking to Dave the other day. He's trying to get a better frequency measurement and I need to help him do that, because I think I got some ideas at how. Throw that PMU away and good riddance.

Jess Slater ([01:20:08](#)):

So I'd like to take you back to your time at JPL. You talked about these differences between the engineers and the scientists and how you could see even from their clothing, and I'm assuming with their approaches, analytically how they're looking at data. And so I'm curious, do you have any examples of how these two groups work together successfully trying to tackle a technical problem related to power systems?

Harold Kirkham ([01:20:34](#)):

Unfortunately I can't. The difference in their dress is fairly obvious, easy way is to look at the shoes. And this doesn't give it away because these are sneakers, but if they're wearing scientist shoes.

Julie Cohn ([01:20:57](#)):

Scientist shoes?

Harold Kirkham ([01:20:57](#)):

Actual Birkenstocks are, of course, the thing if you are in science. But the power stuff was really handled by the power side, the engineering side of JPL in the technical divisions. But there, the technical divisions are separate from the science divisions and the interaction there is not zero. They do work together. But it didn't happen to work together on anything that I was involved in power. I knew I was; I feel funny saying this, but some of my best friends that—they were scientists, so there you are. In fact, I had a phone call from one last week who left JPL about when I did. And she calls up and just checks on how I'm doing, and so on. She was, she was in charge of a big database of atmospheric data, but I was very fond of her. She was great fun. You'd go sit in her office and she'd give you a little look and she'd say, "The microphone's over there today." Okay. Anyway fun people, fun place to be.

Jess Slater ([01:22:18](#)):

So thank you so much for spending your time with us. We'll end with just with one last question. Is there any advice you'd like to give to students today or young engineers?

Harold Kirkham ([01:22:31](#)):

I'm sure there is. I'm try to sort through what I would think is the—if I had to say, one thing, what would it be?

Harold Kirkham ([01:22:44](#)):

Try and get practical somewhere. Perhaps not for your lifetime, but learn. I think there's a lot to be gained by getting your hands dirty. I'm a lab rat; people think of me as highly theoretical, but it's not true. I'm a lab rat. I had a lab when I was an undergraduate. I had a lab when I was a graduate student and I missed the fact; I have a lab at home now. .

Jess Slater ([01:23:13](#)):

Thank you so much.

Harold Kirkham ([01:23:15](#)):

You are very welcome. I hope this has been as much fun for you as it was for me, but I don't think so. I hope it is tolerable.

Julie Cohn ([01:23:21](#)):

It's been terrific. Thank you very much.

Daniel Molzahn ([01:23:23](#)):

Oh, this has been great.

[End of Interview]