

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

Interviewee: Sakis Meliopoulos

Interview Date: July 22, 2024

Place: Seattle Convention Center, Seattle, WA

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

Transcriber: Temi online

Keywords: Sakis Meliopoulos, Georgia Institute of Technology (Georgia Tech), National Technical University of Athens, Greece, Bell Telephone System, telephony, mainframe computer, minicomputer, PDP11, Data General, Nova Minicomputer, plasma display screen, interactive power flow software, Electric Power Research Institute (EPRI), ASEA Brown Boveri (ABB), Hitachi, microprocessor, diakoptical solution, George Cokkinides, Advanced Control Systems, positive sequence model, electromagnetic transients program (EMTP), Monte Carlo simulation, extended probability simulation, Power Authority of the State of New York/New York Power Authority (PASNY/NYPA), phasor measurement unit (PMU), Power Systems Engineering Research Center (PSERC), Edmund Schweitzer, Antikythera mechanism.

Abstract:

Sakis Meliopoulos, Georgia Power Distinguished Professor in the School of Electrical and Computer Engineering at Georgia Tech, reflects on his educational and professional background and work on power systems. He begins by describing his early attraction to science, mathematics, and engineering. He discusses weighing professional positions in industry and academia and his decision to pursue research at a university. He points to the 1965 Northeast Blackout as incentive to find computer models to address operational control and system stability. He describes the transition from mainframe to minicomputers and the opportunity to break down the power flow problem and run solutions on multiple minicomputers. He notes the importance of interactive software and the ability to visualize power systems on plasma displays. He notes that the interactive power flow modeling solution

developed in his lab for Westinghouse is still in use today at the successor company, Hitachi. He underscores the challenge of limited computer memory that made computation difficult in the earlier years. He discusses his team's diakoptical solution to power system analysis to address the challenge presented by large matrices. He notes that many other research groups were wrestling with large matrices and sparsity. He recalls that industry engineers sometimes disparaged new ideas that came out of academia, although those ideas became standard approaches. He points out that cost was often a factor. He gives the example of Advanced Control Systems, an Atlanta-based company that worked closely with Georgia Tech on control centers and distribution systems. He agrees that the tools, models, and computational methods developed in the past may not be sufficient for future challenges of power systems and underscores the importance of basic principles in developing models: symmetrical components and actual physical quantities. Dr. Meliopoulos compares extended probability simulation to Monte Carlo simulation. He talks about new measurement technologies and how they may enhance future models. He offers anecdotes about hidden failures that resulted in blackouts in Germany and, more recently, New York City. He encourages students to research their ideas. He discusses the development of PSERC and the importance of industry/academic collaboration. He closes by describing the discovery of the ancient Antikythera mechanism as an example of Greek technical innovation.

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 ([00:00:07](#)):

This is Julie Cohn. I'm conducting an interview with Sakis Meliopoulos on July 22nd, 2024, at the Seattle Convention Center in Seattle, Washington. Daniel Molzahn, who's joining us virtually, will assist with the interview, and Jess Slater is also participating in this interview and may ask questions. Dr. Meliopoulos, during today's interview, we are especially interested in your early work on power system stability, control, and protection, and how it was later carried forward into standardized approaches in the industry. But we'd like to begin with some introductory questions and general background information about you. So, if you would please describe your educational background and your professional positions in the field of power systems.

Sakis Meliopoulos ([00:00:57](#)):

Well, I will start from high school. I graduated from my high school in Greece, in Katerini, Greece, in 1967. I entered the National Technical University of Athens, Greece at that time. And I graduated with a degree in electrical and mechanical engineering in 1972. After this graduation, I joined Georgia Tech to pursue my master's and the PhD. And I received the master's in electrical engineering in 1974, and I graduated with a PhD in 1976. Since then, I joined Georgia Tech as a faculty member, and I've been there since then.

Julie Cohn ([00:01:57](#)):

What attracted you to electrical engineering and power systems?

Sakis Meliopoulos ([00:02:04](#)):

That's an excellent question, I guess. I had an inclination since I was a young person to anything with the science. Not only electrical engineering, but the other things, chemicals and things like that. As a matter of fact, as a high school student, I have a chemical lab in the basement of my house. Okay. Producing some nasty chemicals and just curiosity though. So, as I was growing up, I realized that engineering is my main attraction and that's why I pursue the electrical and mechanical engineering. So that was a dual five-year program at the university, and I followed that. And, as a matter of fact initially I was, I wanted to be in aeronautics and things like that. And I was fascinated with the space program at that time. In any case, I guess, eventually I said that electrical engineering is everywhere. Affects basically every single endeavor of engineering. And that's how I ended up to be an electrical engineering major.

Julie Cohn ([00:03:52](#)):

Were there individuals who stand out in your memory as mentors or people who guided you into looking at power systems?

Sakis Meliopoulos ([00:04:04](#)):

Yes. First in high school I had an excellent math professor. Was, this is not electrical engineering, but he was instrumental in shaping my thinking and so on. Mathematics was a thing that—everything depends on it. And so, the basics that were instilled in me at that time, they were very important in selecting electrical engineering, because as you know, electrical engineering is pretty heavy math. And these, <inaudible> equations that is the basis of electrical engineering are pretty tough. Math things and so on. And so, my background was, says that, I was feeling very comfortable with electrical engineering. Now in terms of actual electrical engineering, there were several professors that fundamentally changed my thinking and reinforced my attitude towards engineering. So, there are several of them. So not go through each one of them, but they involved areas of electrical engineering that was not only power systems, but also the general electrical engineering and what can be done with electrical engineering, various engineering disciplines.

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

Did you consider at all pursuing a career in the industry, or were you pretty focused on staying in academics from the beginning?

Sakis Meliopoulos ([00:06:11](#)):

Yes, I did consider going to industry, but when I graduated with a PhD, I had two interviews with companies, and I realized that this is not my kind of work. Yeah. So, I immediately made the decision that I'm not going that way. And one of the reasons for this was that even as a graduate student at Georgia Tech, I was working heavily with the industry because we had projects, especially with Westinghouse. And I met the research group of Westinghouse that at the time were in Pittsburgh, and they're doing some neat things in power systems. And I realized that in a company, 99% of the company deals with the everyday problems. They have to sell their products, develop their products, and so on. And then there is this 1% that deals with the thinking and what is the research and what is the new things they can develop. And that made a big difference. That's—and that made me realize that this is where I have, I want to be.

(00:07:51):

As a matter of fact, I'm going to tell you an anecdote. I worked with the telephone company at that time. At that time, the telephone company in the US was only the Bell system. And as fact, when they started, they started this lawsuit that broke the Bell system and so on. And there was a person that they invited in the research group to give a presentation on what, at that time they were working on electronic switching. At that time, telephony and so on was all electromechanical and things like that. And the person provided a very good presentation of the possibilities that can happen with electronic switching, and how this can change telephony. And at that time, telephony was the big thing.

(00:08:59):

And so, I realized that in that presentation, that there were people that had different opinions about research and what the possibilities were, new discoveries, and so on. And I remember one person said, "These things, it's okay for research, but they will never reach applications. They will be part of the engineering process for telephony and so on." And I thought, this person doesn't have any imagination. And we know now that everything is electronic switching in telephony and internet, whatever, you name it.

Julie Cohn (00:09:47):

Okay. So, as you began your research career, what was the most important technical problem that you tackled?

Sakis Meliopoulos (00:09:56):

Well, when I started, the most important thing is that we realized that the power system is large and has a lot of problems. As a matter of fact, one of the events that was shaping the thinking at that time was a blackout that happened in 1965. A few years earlier than when I was starting my career. And we realized that this complex system, in order to be controlled and to avoid this kind of events, we have to do a lot of work to develop models and how to deal with the operational control, stabilization of the system, and so on. And of course, the immediate realization is that we have to develop computer models to be able to do that.

Julie Cohn ([00:10:58](#)):

Were you thinking about this in terms of using analog computers or digital computers at that point?

Sakis Meliopoulos ([00:11:05](#)):

Well, at that point which we're talking about 1972, '75, and there were, computers were involved in the time, for example we, before 1970 was basically the idea of a mainframe computer and so on. But then in the period of time of '72 to '73, there was the idea of making smaller computers. The minicomputers were the thing of the future. Minicomputer is basically a small computer with a limited memory but with the capability of a computer to do the computations we need to do. And basically, [during] that five-year period, we focused on that and how we can make minicomputers useful to the power system operation, control, and stability.

Julie Cohn ([00:12:14](#)):

Do you remember who the manufacturers were that you worked with at that point?

Sakis Meliopoulos ([00:12:18](#)):

Yes, there was—the first minicomputer was the PDP 11. And then Data General came with the Nova minicomputer, if I remember the number correctly, Nova. And then the idea was: how we can make these computers be able to do the tasks that we need to operate a power system.

([00:12:53](#)):

And one more thing. There was also a company, that unfortunately folded, because it was ahead of its time. That company did displays, and they called them the plasma displays. That is, if you think about it, it was basically a monitor that had three tubes that would emit color, and that they were using the three basic colors to make a color display on the system. And, they had something like a 512 by 512 display.

So, we can program this to show text and pictures. And as a matter of fact, on this technology, we did the first interactive power flow software.

Julie Cohn ([00:14:05](#)):

Oh, so did you have these displays at Georgia Tech?

Sakis Meliopoulos ([00:14:11](#)):

Yes. It was at Georgia Tech, and was a project supported by Westinghouse.

Julie Cohn ([00:14:17](#)):

Oh, okay. So, the—so was your focus on models for control and stability analyses? Is that the kind of thing you were doing, working on at that point?

Sakis Meliopoulos ([00:14:34](#)):

That's correct, yes. As a matter of fact, we were focusing on one of the basic computational issues in order to do operations control instability analysis. And the basic problem was to solve the power flow problem. Because in each one of these applications, we needed this analysis. And as a matter of fact, I remember in 1974, we came up with the first power flow modeling interactive, operating on a minicomputer and a Nova, that Data General computer, and was capable of solving the power flow of a 500-bus power system. That was unique at that time.

Julie Cohn ([00:15:31](#)):

So, who did any of the utilities then try it out?

Sakis Meliopoulos ([00:15:39](#)):

Yes and no. Westinghouse was basically, was trying to use this basic development into the, into the system that we're developing for operation and control of the system. They were working with EPRI and so on. And they were successful as a matter of fact. We developed some other things for them as well. And as far as I know, a lot of their computational legends today, well, Westinghouse. Let me tell you story about what happened with Westinghouse. They were bought by ASEA Brown Boveri, a company that is known now as ABB.

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(00:16:43)

So, Westinghouse now is part of what we call ABB. And recently, ABB became Hitachi. So, the evolution of the companies happened. Many of the computational basic models they have in their system for power system control, operation, and stability that they're using still, are the things we developed for them.

Julie Cohn ([00:17:19](#)):

That's a significant accomplishment.

Sakis Meliopoulos ([00:17:24](#)):

But nobody knows about this. The new generation. They see it as ABB software.

Julie Cohn ([00:17:31](#)):

Yeah. Dan, did you want to jump in at this point with some follow-on questions?

Daniel Molzahn ([00:17:37](#)):

Yeah, I've got, I've got a handful of questions, Sakis, because it's all really interesting. So, one, you were describing kind of the advent of minicomputers and going away from mainframes, or at least as alternatives to mainframes. Was this sort of well understood at the time that this was the future that

we—everyone was going to be using minicomputers, we have to get the software developed for power flow and other applications here? Or was it something that you really sort of had to sell. That existing industry was very comfortable with their methods and didn't want to change, and you had to convince them that, “Hey, maybe this minicomputer thing is worth looking into?”

Sakis Meliopoulos ([00:18:14](#)):

No, I think everybody realized that the minicomputers can—it's a game-changing hardware and that was pretty much accepted. The only thing that was happening—that is, how can we develop the large-scale systems on the minicomputers? Because the thing about this, it was the memory was limited and therefore the development of software for analysis and control of power systems was, has to overcome these obstacles of limited memory and limited storage at that time and so on. But as you know, eventually those things changed with the—few years later, in pretty much eight years, we had—there is a lot of activity in terms of large-scale integration of electronic systems. And in 1980, we had the microprocessor coming into the field. And then everybody realized that there are going to be microprocessor-based computers. And pretty much now we—what we're dealing with is computer systems that are microprocessor-based, pretty much everything. So, there was a revolution. But everybody realized that simple computer devices are game changers.

Julie Cohn ([00:20:09](#)):

May I follow up on that?

Daniel Molzahn ([00:20:11](#)):

Oh, sorry. Go ahead, Julie.

Julie Cohn ([00:20:13](#)):

Was the power industry out in front in terms of embracing these tools, or did this happen across other industries that you witnessed?

Sakis Meliopoulos ([00:20:25](#)):

Well, it happened to other industries, because obviously that affected everything, every industry that needs computations. Which is everybody.

Julie Cohn ([00:20:36](#)):

Yeah.

Sakis Meliopoulos ([00:20:38](#)):

But the power industry was in dire need of this, because basically they had these computations for real-time operation, and therefore, it was an issue of survival. And everybody pretty much was in agreement that a computational power will avert blackouts in the power system and will improve the reliability of the system.

Julie Cohn ([00:21:16](#)):

Go ahead, Dan. Thank you.

Daniel Molzahn ([00:21:17](#)):

So I'm going to ask you to speculate Sakis, so I may, it's an unfair question, but if the blackout of 1965 hadn't happened, and this sort of computing revolution that was happening kind of in parallel, still happened, do you think it would've, these ideas would've taken on as, as quickly or as enthusiastically as it sounds like they did? Or would there, in that case, have to be more push from people to convince industry to use these tools?

Sakis Meliopoulos ([00:21:53](#)):

Well, definitely was an impetus. The '65—, what happened in '65 was an impetus to seek the solutions. So, you're right. If it did not happen, probably these developments will happen anyway, but will take a longer time, and will not be so emphasis to work on these problems.

Daniel Molzahn ([00:22:19](#)):

Got it. And maybe one other follow-up on this discussion, as well as, so how much—the story that you described makes it sound like microprocessors were just getting better—many—. The computing technology was, was improving, and power grids benefited from it. We've talked with other folks about sparsity and coding methods and other, kind of, algorithmic innovations that came out of the power area directly. So, my question is: how much of the improvements in the ability to do these tasks—like you said, that power grids are sort of on the leading edge of—how much of those capabilities were driven by hardware versus how much was driven by software? Or was it really kind of the intersection of both?

Sakis Meliopoulos ([00:23:04](#)):

Well, I would say it was both. And as a matter of fact, another thing that we did that was, that set up the states to use distributed computing, and so on, it was that other, in every project, we developed the first diakoptical solution to power system analysis. And we've done this on the first personal computer. At that time, they were—now we're talking about in the '80s, basically, there were the personal computers that came out, and one model was known as the AT because it had some improved, more memory, higher processor, and so, in that time—and of course today we have microprocessors that are much more capable than at that time.

([00:24:12](#)):

So, we developed a diakoptical solution, basically taking any problem that we have in the system to solve the differential equations, whether it's a power flow, a control problem, a stability analysis problem, and so on. And so, the basic computational issue was to solve a large matrix equation. And basically, what we did is that we split the matrix in sub-matrices, and we were processing this at different processors on the system. And we were able to solve all these personal computer AT matrices

that are 10,000 by 10,000. And of course, the trick then is to keep the benefits of sparsity, and so on, because splitting these matrices affects how it is split; affects the utilization of the processors we have; and, of course, the efficiency of the solution method depends on what is the processing time of one of the sub-matrices.

[\(00:25:24\)](#):

So, if there—we don't select them properly, then we have a lot of processors waiting for another processor to finish the task and so on. So, we developed a method that will optimize this so that the processing of every sub-matrix would be approximately the same time as any other. So, these are very tough problems, but there was a good solution there to speed up the computations.

Daniel Molzahn [\(00:26:10\)](#):

And that seemed that the silver—, sort of overall method seems very general. The idea of taking big matrix equations, splitting them up into pieces and splitting off across processors. Were you, were the power industry researchers kind of at the forefront of that work? Or were you kind of using ideas from other computer scientists or applied mathematicians and adapting [them] to the power problems? Or kind of a mix of both?

Sakis Meliopoulos [\(00:26:38\)](#):

Yeah. Well, that's an interesting question, because basically the average power engineer that works in the field, he doesn't want to know all these details; he wants to use this, the system. So, we have a lot of people who are using the system. Even if now has evolved. Okay. For example, we have one product that developed out of this area, where we can solve very large network problems, three-phase power flows and so on. But then the diakoptical solution took a very different form now. Okay. So, it evolved, and so we can use problems that are—that we use higher level diakoptical solution, so we can have a parallel solution. For example, the industry is using some of the programs we developed that have to simulate a large system, for example a PV facility, which can be a system that, in terms of representation, in terms of equations, may be millions of equations.

[\(00:28:07\)](#):

So now the same diakoptical solution is done at higher level. And we can use microprocessor-based personal computers. They have many courses—48 courses—and so, we can schedule the solution by sending the computations to the different course. So—and that makes a big difference in terms of response time of the solution method.

Julie Cohn [\(00:28:39\)](#):

I'm not sure you answered part of Dan's question, which had to do with: who was developing the ideas for the sparse matrix using sparsity? Was that coming out of people thinking in the power industry in electrical engineering academia or in other fields entirely like in a computing field?

Sakis Meliopoulos [\(00:29:07\)](#):

Yeah. First of all, the diakoptical solution I refer to was developed at Georgia Tech—my group.

Julie Cohn [\(00:29:13\)](#):

Your group.

Sakis Meliopoulos [\(00:29:14\)](#):

But there were a lot of efforts there at that time to parallel process and do parallel computations and so on. There were a lot of methods, a lot of technical papers that were addressing the—this problem. And so, there was a lot of activity, a lot of research groups trying to address this problem.

Julie Cohn [\(00:29:48\)](#):

Who were some of the individuals with whom you collaborated? Was it entirely within your research group, or did you collaborate across with other universities or other individuals?

Sakis Meliopoulos ([00:29:59](#)):

Well, the diakoptical solution I mentioned was a project from—sponsored by Westinghouse. And there were—I was working with my students. As a matter of fact, one of my students turned out to be very crucial member in these developments by the name of George Cokkinides, Dr. George Cokkinides. And he's a technologist, one of the best I've seen in my life. And we worked with a lot of students that now are graduated and are professors in different universities, and some of them continue this kind of work.

Julie Cohn ([00:30:47](#)):

Were there any individuals who tried to shut down your ideas?

Sakis Meliopoulos ([00:30:53](#)):

No, I don't think.

Julie Cohn ([00:30:54](#)):

Or was it well received? Like if you came to IEEE to present a paper on this, was it well received?

Sakis Meliopoulos ([00:31:01](#)):

Well, I would say the majority—they saw the ideas that are useful, and so on—but also, we have distractors that—people—they said, "This is never going to work," and things like that. But that's normal.

Julie Cohn (00:31:20)

Dan, I didn't mean to interrupt.

Daniel Molzahn ([00:31:22](#)):

I had a couple other questions that were spurred from your earlier conversation. So one, you had mentioned this display with the 512 by 512. So was that intended, and you said you were solving power flows and showing it on this display. So was the key innovation there, it sounds, it seems like, was the ability to visualize the power system in putting power flows on this display and kind of lighting up in different colors. Was that—is that the right interpretation that was really—it was the visualization aspect for engineers to be able to see better what was going on?

Sakis Meliopoulos ([00:32:02](#)):

Oh, yes. As a matter of fact, the this was, I would call it an interactive computational lens, because basically as it was displayed the diagram of the system, I can go to a bus and I click on the bus and say, "What would happen to the system if the load on this bus changes from this value to this value?" So, it was any directive kind of power flow that will provide all this information.

Daniel Molzahn ([00:32:35](#)):

Got it. And so, then this display allowed that interactability to—

Sakis Meliopoulos ([00:32:41](#)):

That's correct.

Daniel Molzahn ([00:32:42](#)):

To be used. I see, I see. Then kind of along the same—or the other question that came to mind—when you described this—so it seemed like you said this company went out of business, they were ahead of their time. And so, it just seems like the computing world was moving so fast, is the impression I get from, from those days. So, as a researcher, and in the industry, how did you kind of plan ahead? You presumably invested a lot of time into this display, and then the company goes out of business and your methodology that you built, or at least the implementation of it, is no longer directly applicable. So how, how did people kind of navigate that world where the technology that you're building upon might not be there next year? It might be something completely different.

Sakis Meliopoulos ([00:33:32](#)):

Well, what was happening in that time, I guess, was that there was a lot of activity on improving the control centers. Because as you know, in the control centers, there are all of these computational tools that have to be there and so on. And there was great demand for these visualizations and, their activity, on the computational tools. Okay. When this company went down, some other companies came up with other systems that will do similar things, but the cost was prohibitive. So, for example, for one terminal at that time was \$60k, and so on. So, in a control center, you need 20 of these, and so on. So, the cost was very prohibitive. And there was a period that they said, "Well, we have to wait until the prices come down a little bit to be able to do that."

([00:34:40](#)):

And as you know that there was a lot of work in this area. And as a matter of fact, Atlanta had its own Silicon Valley with companies working on new displays and bringing down the cost and so on. And there were some companies, they developed the early new displays that will try to mimic this interactivity, interactivity in the system. And some of the systems were useful and were being adopted and so on. And of course, when the LED industry developed, and so on, we have now the very nice screens that are fully interactive. And the rest of it is history.

Daniel Molzahn ([00:35:46](#)):

Interesting. I didn't, I didn't know that was in Atlanta, or that there was a sort of big center of that in Atlanta. Is that still here? I should probably know this, but—

Sakis Meliopoulos ([00:35:55](#)):

The '80s were, as a matter of fact, there was the one—there were two brothers by the name of Landreth, and they were very big supporters of Georgia Tech, because basically, they were supporters of Georgia Tech because Georgia Tech also will help them within technology, so—and they developed some new systems there. And as a matter of fact, one of the brothers there develop a company that was specializing for control centers, for distribution systems utilizing this technology. And this company still

exists in the, in Atlanta by the name Advanced Control Systems. But also, they've been bought several times from other companies. So now these brothers are older—one has passed away, the other is still alive—but the company has changed hands since that.

Daniel Molzahn ([00:36:59](#)):

Got it. Interesting. So, Julie, I had maybe one other question, but I don't want to kind of take over the whole conversation, so if I'll maybe ask one more question, I'll pass it back to you.

Julie Cohn ([00:37:12](#)):

Okay. sounds good.

Daniel Molzahn ([00:37:13](#)):

So, you had mentioned, and I might be stealing Julie's question, I suspect she might ask this as well. You had mentioned some of the models and methods that are really at the heart of a lot of what—the tools we use today were things that your group had developed and were kind of generally developed several decades ago. So one thing we're trying to understand as part of this project is to better characterize what kind of assumptions went into those models and what sort of underlying methodologies that, that were developed to address these problems that, that we had in the power system which have been very successful over many decades, which of these are still going to be relevant going forward? And which things do we have to rethink? And I know you're obviously still very active in kind of the energy transition and everything happening today. And so, I suspect you'd have a pretty strong perspective on the tools, models, and computational methods that we've developed in—and have been in wide-scale use. What can we keep and what do we have to change?

Sakis Meliopoulos ([00:38:24](#)):

Yeah. That's a big problem. And as a matter of fact, I see the newer generation that is not following what I'm always pushed to be followed. We have to go to the basic principles. And there are only a few basic principles: that is, in developing these models, we have the option to model a system with symmetrical

components and another option to develop it in terms of actual physical quantities, actual voltages, currents of the different phases and whatever else is involved in the system. Now—and this is valid today as well—I just finished the working group meeting here where I said, "We have to have today two models.

[\(00:39:39\)](#):

One is symmetrical components, and we need to understand that this is an approximation of what's happening in the system, and then a three-phase model which represents everything in the system." That's all that is very simple. And basically, many of the tools that we still use in the power industry are based on in terms of what I'm talking about here, is in terms of what we call the positive sequence model of the power system. And we need to stick with that and make sure that we develop the positive sequence model using first principles and base everything on these models. Now on the other hand, depending on what we want to do, whether it is stability or power flow or other applications, we have to have models that represent correctly the physics of what we try to study. And that's a very, it's a much more complex question because I worked also on what we call EMTP-type of models where we have models that are represented in the physics at high frequencies for the power system. And these models are different from what we use for power flow and so on. But again, we can use the first principles to have the correct model for these applications.

[\(00:41:28\)](#):

And another thing that I forgot to mention is that the power system has a lot of events that are statistical in nature. And for example, for planning methods we have to consider all the uncertainties associated with the power system. And back in the early, the days we were doing the models for Westinghouse, we developed also a probabilistic simulation of power systems by taking into account the random events that can change the—both the topology and how many resources are available in the system. And that was also the first in the industry at the time. And the—based on that work, Westinghouse developed a full planning tool for the industry. So that's in addition to the control operation of the system, to have a planning tool that will predict what will be the—not only the projected cost of the system, but what would be the projected utilization of various fuels in the system.

[\(00:42:57\)](#):

And it can be used for the—how a power company can run the system. For example, it has been used by the industry to say, we have this system and we need to determine what is the best way of ordering fuel for the power plants, what is the predicted need of fuels for the next month, for the next three months, and so on. So that's very important issues as well in addition to control operation and stability of the power system. And as far as I know, this model still is used by the ABB basic planning tool, it is the computational lens of their product.

Julie Cohn [\(00:43:52\)](#):

Do you see that changing as more and more distributed energy joins the networks?

Sakis Meliopoulos [\(00:44:00\)](#):

Absolutely. I'm glad you asked this question because well, let me rephrase this with what's happening in the industry now, that is, because of the addition of the of the new resources, renewables and so on, so pretty much everybody thinks that the way we can start, we can deal with these systems is to use the concepts that are in what we call Monte Carlo simulation: that is, to do many trials of what the system is going to do. Basically, statistical trials. Say, okay, this is the time, is a statistical trial, is that we have so many available of the resources: wind, PV, and so on. Let's do a simulation of the system where it will happen and then take another trial where the different renewables will be available and so on.

[\(00:45:11\)](#):

And then of course, when you do this, you have to do a lot of simulations, a lot of computing power, to come up with some results that are statistically significant. Well, since there is the work I did with the probabilistic simulation on power systems, my work has moved to other areas and so on. But it is easy to extend the statistic—, the probabilistic simulations, which are analytic in nature, to include the new renewables, and so on. They are more complex models because, as you know, renewables are not dispatchable. So, we have to have different ways of dealing with this in a probabilistic simulation of the

power system. But it's doable. And I'm trying to talk to some newer folks and so on, and new talent in the power industry to spend some time on these problems. <Laugh> Instead of doing Monte Carlo approaches, which is—they're fine, but I don't think we have enough computers to do all the simulations we need to do.

Julie Cohn ([00:46:37](#)):

I'm not sure how to phrase this accurately. In the extended probability simulation, is there a place also for generation that's not owned by anybody but an individual?

Sakis Meliopoulos ([00:46:53](#)):

That's correct, yes. Okay. Because these systems also have probabilities that may fail. And therefore, we need to take into consideration, normally these people operate in terms of markets involved in the system through the markets. So basically, we have to model this, go back to basic principles and model them properly so they can be included in a probabilistic simulation approach.

Julie Cohn ([00:47:26](#)):

Dan, did you have a follow on that, or—?

Daniel Molzahn ([00:47:28](#)):

No, no, I think that's really interesting, but I don't have any follow-up questions to it right now.

Julie Cohn ([00:47:35](#)):

Okay. I noticed—well, did you have something, Jess?

Jess Slater ([00:47:38](#)):

I did. I had a few questions, but I can just ask one right now. You said you had an overall inclination for science, and so you mentioned some things like chemistry, physics, aerospace, statistic. And I was curious, do you have an example of how ideas from an untraditional discipline approached—influenced how you approached solving any technical problems you were having?

Sakis Meliopoulos ([00:48:05](#)):

Well, assume you're talking about—that is, how we can get ideas from other areas and include them. Absolutely. This is happening all the time. As a fact pretty much today, we believe that the new ideas that can come in the power system is coming from the edges of the science. That from other areas and so on. The probabilistic simulation model is an example that came from other areas, not the power system and so on. And the—well, first of all, in terms of technology for the power system, there is a change in paradigm in the technologies in power systems that they have to do with how we take all these computational efforts and models and so on to include them into the system.

([00:49:22](#)):

And the technology that is coming from other areas, for example, measurement technologies and so on. They found its way into the power system. And now we have new opportunities to change the way we do solutions. For example, one thing that I'm pushing these days is the following: that is, these new technologies that came out from other disciplines. Okay. We can utilize them to solve a very important problem for power systems. Okay. And that important problem is how we model the power system in a way that is realistic. And it is, it doesn't have errors. Because the, a perennial problem we have in the power system is that we build the models, but then we have humans that make errors, and we find that the models are not correct for a particular application. Okay. As a matter of fact, I tell my joke in the groups that my favorite blackout in power systems happened in Germany about 10, 12 years ago.

([00:50:48](#)):

Yeah. And the story for this blackout was the following: that is, they have a transmission line that crosses the River Rhine in Germany. And a boat was traveling on the line, and they called the control side of the power company and says, “We're going to cross that point. We have a very long mast, and

we're afraid that it may come very close to the transmission line, and we want you to turn the transmission line off, so we don't have an electrical charge, electrical discharge. So, the operator did the analysis and said, "Okay, what would happen to the system if we remove—if we trip out this transmission line?" So, they came up with, "Nothing is going to happen, the system's going to continue to operate normally," and so on.

[\(00:51:47\)](#):

And when the boat approaches there, they tripped the line and the whole area experienced a blackout. So there was a postmortem analysis of—all of this is in the public domain. And the conclusion was that the model they had—they used to do this analysis was incorrect. And that's why they gave them the wrong information, that everything will be fine with the step-out. And the blackout was history. So, if you look at every, every major event that involves a blackout, there is always two things that coming up: is some protection and control did not work properly. And some model we had for the system was not the correct model.

[REMOVED FROM THE TRANSCRIPT]

[\(00:52:53\)](#):

So, the perennial problem is that we have a lot of human error in the models of the system. And now with the new technology we can change our computational procedures to make them to the point where they can check whether the models we have are correct, whether there are any hidden failures in the system. We have another problem, of course, in the process, and that may be a hidden failure. For example, we're measuring a voltage somewhere in the system, and the wiring we use to take the actual measurement experiences a short. Many times, these kinds of things, they go unnoticed. We get—especially if we measure the current in the system, if there is a short and it says the current is very low, nobody notices that.

[\(00:53:55\)](#):

So that can be a normal system, thing on the system. But then these kind of faults, they can generate problems if there is an actual fault in the system and the relays have to control the system in a certain

way. So that can be secondary events that they can lead to major blackouts. As a matter of fact, we did have a major blackout in New York City, in 2019 because of an event like this. There was a hidden failure and something small happened to the system, and suddenly we have the whole city of New York out of power. And so, these technologies that come from other areas, now can be very useful to solve this problem, to validate models, to determine whether we have hidden failures in the system, so we can avoid all of this.

Jess Slater ([00:55:06](#)):

Thank you.

Sakis Meliopoulos ([00:55:07](#)):

So definitely there is a big issue there.

Jess Slater ([00:55:12](#)):

Do you want me to ask another question or—?

Julie Cohn ([00:55:14](#)):

Sure.

Jess Slater ([00:55:14](#)):

Okay, perfect. Alright. So, you spoke earlier about how some frameworks or some approaches are okay for research, but they would not necessarily apply for applications in real life. Why do you think there's often a gap between academic research and practical applications within power systems or within what's published?

Sakis Meliopoulos ([00:55:40](#)):

Well, I think all academics are researchers. And from this point of view we need to—any idea that is out there, we need to investigate it: how far we can go with that and so on. But of course, there is always a long time involved to take an idea and make it to a point where it is useful. And so, I think that will be the normal operation for researchers.

Jess Slater ([00:56:20](#)):

And what advice would you offer to students or younger individuals who are entering the field to make their work more applicable within their papers?

Sakis Meliopoulos ([00:56:34](#)):

So, well, the advice I give to my students, “You get an idea, keep on working on it.”

Jess Slater ([00:56:41](#)):

Okay.

Sakis Meliopoulos ([00:56:42](#)):

Don't worry about the applicability and so on. If your work leads to something that will be applicable, then everything's going to work nicely. Okay. And as a matter of fact, today in universities, we have a big push to make the students think as entrepreneurs. And many times, I talked to, I went to meetings where I was, and I said, "At this point in your career, don't worry about entrepreneurship; just worry about ideas. How you can move the ideas along and so on. And once an idea moves along, it can become something that is practical and people want to use it. Then entrepreneurs is going to take care of the—of the whole process." So just doing the work and basically taking the ideas and working on the ideas is the basic—greet it, and then the rest of it—activities, it'll work out itself.

Julie Cohn ([00:58:11](#)):

One thing I'm curious about is the transition from modeling systems in the back room to modeling systems in real time. And I know that that happened over the course of a couple of decades. I'm assuming you had a front seat to that process.

Sakis Meliopoulos ([00:58:31](#)):

And we have a lot of committees here working on this problem.

Julie Cohn ([00:58:36](#)):

Yeah. So, what is your sense of when utilities felt they had enough confidence in the computer models to be able to link up to real time operations?

Sakis Meliopoulos ([00:58:57](#)):

Well, I'm going to split the question in two.

Julie Cohn (00:59:00):

Okay.

Sakis Meliopoulos (00:59:01):

First of all, when utilities realize they need models to operate the system—that goes back before I was even born—this idea is: it was there always. Now the question is, if we solve this problem? I would say, not quite yet. We have to do a lot of more work. Because the example I mentioned before that we have new measurement technologies and so on, we have not taken full advantage of this. So basically the models are still a combination of human work and computer work that we have gotten to the point where we can use the computers to automatically provide the models without any human errors and so on. So, we can trust them. How utilities trust the models? Well, it depends on who you're talking to. If you talk to persons that are doing the investigation after a major blackout, they know that we're behind that or they will not trust the models. But what's happening? Human nature. That is, after any blackout,

we talk about these problems, but then six months later after the blackout, everybody forgets about it. So we still have to do a lot more work.

Julie Cohn ([01:00:34](#)):

Well, speaking of blackouts, I noticed that you were interviewed immediately after the 2003 Northeast Blackout. I'm curious to know how that came about and how the response to that blackout may have affected your follow-on work.

Sakis Meliopoulos ([01:00:50](#)):

Yeah. Well, that was an interesting blackout and because I was involved with the data acquisition that operated during that, that blackout. Specifically, one thing we did at Georgia Tech is that we develop synchronized measurements. And as a matter of fact, we did this work for New York Power Authority, and then they took our work and they hired a company in New York by the name of Macrodyne and Macrodyne built, based on what we did at Georgia Tech, the first PMU, the first commercial PMU unit. There are many other people that claim they did the first PMU, but really nobody else did. It is—that was the first PMU that had synchronized measurements.

([01:01:55](#)):

Oh. There were some other efforts by some Canadians, another university, and so on. But they were not synchronized measurements, were what we call multiplexed measurements. Yep. And utilizing this technology we developed a system for the New York State where we installed Macrodyne PMUs throughout the state and were collecting synchronized measurements. And we had the control center that were, will accumulate all these measurements and see what's going on in the whole State of New York. As a matter of fact, this control center was, for a year, was at Georgia Tech. And then eventually we moved it to White Plains, where the headquarters of New York Power Authority was there. And then and that system, we developed it in 1993, and it was operational until five years ago. It was still operational, but the equipment was replaced. So, it's—and then when the 2003 blackout occurred — then this system captured all the data: what were the oscillations, how the system was split, and things

like that; and it was an enormous amount of data. And in the interview, you mentioned, people were thinking that somebody put a bomb in— —that's why they asked—

Julie Cohn ([01:03:45](#)):

We shouldn't laugh, but—

Sakis Meliopoulos ([01:03:46](#)):

New York Power Authority has a very large facility on Niagara. Basically, we use the water from Niagara to generate the power. So, they were thinking that they put a bomb there because the voltage went down to 40% during that event. Yep. And I was telling them this was still really, this was an oscillation of the system between New York and Ohio and so on. And so, it was normal. And the—this system showed that it was just a normal oscillation of the system but caused the rest of it.

Julie Cohn ([01:04:26](#)):

Interesting. And did you then, were you engaged with any of the follow-on examination of the blackout? I know that NERC put together a committee that worked on that, and

Sakis Meliopoulos ([01:04:39](#)):

Yeah, NERC put a committee. I was not part of the committee, but I worked with New York Power Authority to analyze the data, what happened to their system, and so on.

Julie Cohn ([01:04:50](#)):

Interesting. Okay. We've taken up a good hour of your time. I guess I should see—Dan, do you have more questions you want to ask?

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

I do have a few more. I also get the chance to walk down the hall and ask Sakis these questions when, when we're both back in Atlanta. But one topic that I think we hadn't touched on as much is kind of the, just getting your perspective on the role of the development of the way that we disseminate research. I know you were quite involved in PSERC when, when PSERC was getting started, the Power Systems Engineering Research Center and kind of the conferences and other venues kind of associated with that. And I'm curious to kind of, if you can reflect a little bit on how that all came together and what the role of universities and industry working together are, and particularly in venues like PSERC or these other kind of industry university collaborative endeavors. I just know you've had a large role to play in a lot of that. I'm curious if you have thoughts on this.

Sakis Meliopoulos ([01:05:59](#)):

Yeah. Basically, the industry is the—a very good source of ideas. Because basically, I believe the following: that in university we have the talent. That if somebody tells, I have this problem, then we can find a way to solve the problem. That's, I believe this very strongly. And the PSERC, the idea of the PSERC is simply that. It's to bring together universities and industry to discuss things. And as a matter of fact, Dan knows, the way we operate at PSERC is that to bring together industry and universities and have the industry tell us what are the problems they're facing. And then discuss these things and see what things we can do to provide solutions to, or to the problems. Because I strongly believe that once we understand what the problem is, then the solution follows, whether it is a new computational procedure, whether it is a new way of integrating previous work to solve a solution that that can be worked out. And so, and even before PSERC, and as a matter of fact, Georgia Tech, we have an approach that we have. We include industry very heavily in our research activities. And if I look at my work at Georgia Tech, I've been spending more time talking to the industry, over the four and a half decades that I've been there than talking to Dan in the corridor.

Daniel Molzahn ([01:08:08](#)):

Got it. No, that's great. Julie, do I have time for a couple more questions?

Julie Cohn ([01:08:15](#)):

Yeah, I think. We should probably wrap up in the next 10 minutes.

Daniel Molzahn ([01:08:18](#)):

Okay, great. I'll try to keep them short. So another question I had was, you made this comment earlier that in the context of the telephony switching, that there was—technologies that were, were kind of—people in high positions at the time said, these will never get adopted, that's an academic exercise, that will never have relevance. And obviously that was not the case, in that industry. Are there examples that are particularly memorable for you in the power industry where people had said, "This is a crazy idea, we'll never do this," or this is something that academics care about, but never will actually have an impact? Are there examples like that that you could think of?

Sakis Meliopoulos ([01:09:10](#)):

Yeah, there are, I have some real good jokes. Not, they're not jokes, they're reality. It happened. So, the first one I'm going to start is the following: This the in 1970, with Westinghouse, we had the first computer relay. It was done on the PDP 11. And so basically instead of using electro-mechanical relay we were using a PDP 11 to do the computations for the protection and control. And that was installed in one substation, by the name Tesla in California and so on. So, it was operational and proved to be a good relay. As a matter of fact, it was dismantled only 10 years ago. And of course, the issue there was that the PTP 11 at that time was about a \$50k device.

([01:10:25](#)):

So, the issue was that, well, we cannot afford \$50,000 relays. But you know what happened in '80? So, the microprocessor was invented and then one professor in Washington State University by the name of Edward Schweitzer. He built the first microprocessor relay, mimicking what was on the PDP 11, on that relay. So, a microprocessor costs a lot less money. And he was presenting the microprocessor-based relay in one of the general meetings. Well, we did not have general meetings at that time, we had had winter and summer meetings, so it was in the summer meeting. So, he was presenting there, the new relay, and a person from the industry which I will not name, he raised his hand, "Are you going to put this flimsy microprocessor in my substation? Over my dead body!" So this is a good example where

some people did not realize the potential. And of course, the story is that this person retired as a standard manager of a power company. But Ed Schweitzer now is a multi-billionaire and owns 40% of the protection and control industry worldwide. So that's a good example that really—

Daniel Molzahn ([01:12:16](#)):

Yeah, that's a great example.

Sakis Meliopoulos ([01:12:18](#)):

You see. But we need to be open minded and say—if there is a good idea—let's say, “How can we progress with that?”

Julie Cohn ([01:12:34](#)):

Yeah, that's a great story.

Daniel Molzahn ([01:12:37](#)):

Alright, so maybe I'll ask one more sort of esoteric question that I think might be quick and I'll then I'll pass it over to Julie. I know you're also very involved in the, sort of, Greek power engineering, Greek electrical engineering community, and there's all these—Greek as in from Greece, not the Greek fraternities. And I'm just curious, what it is? Because there are so many fantastic Greek power engineers, in this field, and I'm—is there something in the sunshine or the islands? Or what is it that has led to such an impactful power engineering community coming out of Greece?

Sakis Meliopoulos ([01:13:17](#)):

You don't want me to start on that.

Daniel Molzahn ([01:13:20](#)):

I said it'd be quick, so I don't know if it'll be quick.

Sakis Meliopoulos ([01:13:24](#)):

Well, I don't know. The genetics—as you know, the ancient Greeks, they discovered a lot of pro—a lot of things. As a matter of fact, one thing that is from whatever the discovery is the—what is known as the Antikythera mechanism. This is a device that was built—well, it was built a hundred years before Christ. And there was a, it was probably on a boat and the boat sank because of a storm and so on. And this thing was there in the bottom of the ocean for many centuries and was discovered in 1908, accidentally. When it was discovered, [it] was just a block of rusted things.

([01:14:30](#)):

And nobody knew what it was, but then we said, "Well, it was in the—so it is ancient, so let's keep it." And then about, what, 30, 40 years ago, Xerox developed a method of x-rays to read what does it, what is in the rust that's on. And they discovered there was a very elaborate mechanism that looks like a Swiss clock. And so, this generated studies of a lot of people, what it was, what it was used for, and so on. It turned out that it was a calendar with very much detail about the moon phases and the small variations of the calendar, because of the motion of the moon and so on. And there are a lot of materials still in it. And of course, the mechanism is now in the museum in Athens, and so on, for everybody to go and see. So that was a marvel of technology and how they could do that. And of course, there were a lot of good mathematicians and so on. So, I think that this, somehow, we inherited part of the mathematical-oriented mind from our assessors. And so, once we have the mathematics correct, then everything else follows.

Julie Cohn ([01:16:12](#)):

That's great.

Daniel Molzahn ([01:16:13](#)):

That's great. I appreciate the answer.

Sakis Meliopoulos ([01:16:16](#)):

Thank you for giving the opportunity to be a little bit braggy about Greeks.

Daniel Molzahn ([01:16:22](#)):

All great; I appreciate it, Sakis. Julie, I'm happy to turn it back. Like I said, I get to ask Sakis questions quite frequently, so I'll pass it over to you, Julie.

Julie Cohn ([01:16:32](#)):

Thank you. Thank you. This has been a really interesting interview, and we really appreciate that you carved time out of your day to spend it with us and talk about the things you've worked on over the last several decades. So, thank you so much.

Sakis Meliopoulos ([01:16:44](#)):

My pleasure. Thank you. It was an excellent discussion. Thank you.

[End of interview]