Algorithms & Power Systems Architecture:

Using Historical Analysis to Envision a Sustainable Future

Oral History Project

Interviewee: Alexander Papalexopoulos

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

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Abstract:

Alex Papalexopoulos, born in Greece, discusses his professional career following completion of a Ph.D. in power systems in the Electrical Engineering program at Georgia Tech. He initially worked for Pacifica Gas & Electric Company in San Francisco. He explains that he formed his own company, ECCO International, Inc., in 1998 in response to the opening of wholesale power markets in California and elsewhere, as he and his colleagues recognized that market design would be an important new direction in power systems engineering. His company designed markets in fifteen countries. He offers that the US has the most efficient market design in the world, despite problems with decarbonization and renewables. He describes the Systems Engineering Group at PG&E and efforts to solve real-time optimization problems. He appreciates the diverse backgrounds of the team. He speculates that PG&E invested in R&D to address nuclear power and regulatory challenges. The group distinguished this utility from others. He

explains that, due to new objectives, market design going forward will be different from the approaches taken 20 years ago. He gives the example of the effects today on European markets of the Russia/Ukraine war and the need to protect customers from price spikes. He explains the benefits and shortcomings of zonal pricing and his more recent preference for nodal pricing, using the California market as an example. He discusses loop flows between European countries and the challenges created in zonal markets as a result. He references the role of energy traders in influencing market design in Europe. He discusses the role of Gazprom in European power markets. He speculates that utilities in Europe may game markets, but not to the extent that they will break the system. He references Enron's role in upending early markets in California. He discusses today's challenges in market design and meeting the NERC standard for area control error (ACE), which now requires Balancing Areas to meet an ACE of zero at least once every ten minutes, but market clearing every ten minutes does not reflect minute-to-minute operations. The difference between market clearing and operator decisions create problems. He discusses challenges to investment decisions related to industry and regulatory structures but pinpoints the intermittency of renewables as the key to achieving NERC standards. He discusses the opportunities presented by artificial intelligence for solving increasing complex computations. He closes by encouraging engineering students to study financing, economics, and project management in order to be both problem solvers and advocates in the power industry.

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:

Jess Slater (00:00:35):

This is Jess Slater and I'm conducting an interview with Alexander Papalexopoulos on Tuesday, July 23rd, 2024, at the Seattle Convention Center in Seattle, Washington. Daniel Molzahn will assist with the interview. Julie Cohn and Babak Taheri are also participating in this interview and may ask questions. During today's interview, we are especially interested in your work on optimization of power systems and how it later was carried forward into standard practice in the industry. We are also interested in how this translated to your later work in competitive electricity markets. We'll begin with some introductory questions and general background information about you. Could you please describe your educational background and your professional positions in power systems?

Alex Papalexopoulos (00:01:42):

Okay. My first degree comes from Athens, Greece. I'm an electrical engineer. I came to the US, to Georgia Tech, where I got my master's and my PhD in power systems from the EE Department in Georgia Tech. After my graduation, I moved to San Francisco from Atlanta, and I joined Pacific Gas & Electric Company in downtown San Francisco. Pacific Gas & Electric Company is the utility, the energy utility, for Northern California, based in San Francisco, California. I worked for PG&E in various roles, went up to senior director, for about nine years. And at that time, it was the beginning of deregulation in California, one of the first states in the United States to open up the energy system to a competitive marketplace. So, I decided to move on, leave PG&E, and start my own company.

(00:03:11):

It was not an easy decision. I had two young children, one at two years old, but my wife was very—actually—persuasive that I should leave PG&E and start my own company. And that's what happened. I started ECCO in 19-, 1998, based in San Francisco, California. And the objective of the company was to do market design in various jurisdictions. Starting from California, at that time, all the markets were opening up—in Texas, in Pennsylvania and New York. And of course, international markets in Central and South America, at Western/Eastern Europe, and later Asia. My background is really optimization. So, we are basically math people. And how little I knew that basically all this background, 70-80% of our work in market design, is basically optimization. That's what we do. So, I had built a group at PG&E; a very powerful group of about 30 PhDs in various disciplines, from statisticians, mathematicians, electrical engineers, economists.

(00:04:43):

It was a great group. We were kind of the brains of the company. But when the market opened, we had great opportunities. And I was hoping to get some of the people I work with in my group to come with me. Well, it didn't work this way. They said—everybody, I guess, was low risk—"If you're in business two years from now, we'll join you, but you go first." That's what I did. And actually, it exceeded my wildest expectations. I mean, the company has grown. We have designed now energy markets in about 15 countries. Of course, in North America, in the US, but also Central and South America, Western and Eastern Europe, and Asia. So, we have designed basically about 15 countries around the world. We're still very busy. Right now, we're designing the energy market in Chile; so, going off to Santiago; the energy market in Denmark, out of all places; the energy market in Israel.

(00:06:02):

So, we visited, we had meetings in Israel before the war, after the war, we're meeting in neutral places like Berlin or Vienna, nice places. So yeah, we're into market design for energy in many, many places. So, there are many differences. I strongly believe the market design we have here is the best in the world. It's the most efficient. We have problems with decarbonization and renewables, but nevertheless, it is the best market based on sound economic principles. Something we take here for granted is not granted for other places, especially Europe. Europeans are very—they don't really trust markets. They open them up slowly with a lot of rules, a lot of activity rules, to try to contain the market. So, it's a very different structure, very different structure. So, the idea that you take one design from one country to take it to another does not work well. Each country has its own political, commercial, operational constraints. It basically, I would say, "Politics is the inner layer of the onion." We are the outer layer. We follow the principles that they give us, especially policy states or governments. So based on that, we build a design consistent with those principles.

Julie Cohn (00:07:49):

Can you take us back a little bit to your dissertation work and then your early work with PG&E? What were the optimization problems that you were trying to solve?

Alex Papalexopoulos (00:08:03):

Oh, sure, sure. My PhD in EE was on energy modeling. A lot of optimization work. We did a lot of software. It was great training actually. I have fond memories of the EE department of those days. And now I see that it is getting bigger and bigger and bigger, is growing. So, it's great.

(00:08:32):

At PG&E, I thought, "I'm on top of the world. I have a PhD. I know everything." It was a very sobering experience. Okay, let's put it that way, a very sobering experience. You learn certain things in school, but basically you are naive about the practical world. So, the group I joined, I was lucky, it was called the Systems Engineering Group. It's a unique concept in the industry at the time. We did all the development internally, usually utilities being risk adverse. If they want something special, they go to a consultant or they go to a school or they—so they outsourced those things. PG&E had a different philosophy about this. They want to develop everything internally, and they had a very forward-looking CEO at the time and build that group. I was lucky, I was one of the first ones to join that group when I graduated from Georgia Tech. So, we start solving real problems, optimization problems. And I had the opportunity to work with people that were not doubles. They were not engineers. They were economists. They were operational research people that have a very different view how to approach a problem. So, I learned from this experience very much, meaning that I realized that the best contributions come from groups that come from different perspectives.

(00:10:09):

Because in school we're all doubles. We've used certain things a certain way. But when you put in the group economists that challenge a lot of things that we take for granted or operations research people, then, and math people, then you have basically a team that can tackle the problem from different ways. This was a very—I mean, a very important experience for me. So, we solved problems. Let me put it this way, some of the software we developed at the time, after 30 years is still in use at PG&E. I mean, this is amazing. We had the ability to hire people, young PhDs, in the following four or five years from schools. We developed—we were ahead of universities on neural networks and artificial intelligence because we had a huge budget on R&D. Something that does not exist today.

(00:11:10):

Today with deregulation there's no R & D, really, in utilities. So, it was a good time for us to move on because we had millions and millions of dollars of R & D. That gave us the ability to hire people, keep hiring young PhDs. So, we had an ecosystem that was, I think, unique in the industry in the US. People recognized that. But after deregulation, meaning '97, when we start to open up markets, great opportunities were created for us outside PG&E, and many of us did that, moved on. Some of them became professors; some of them started their own companies; some of them did other things with national labs, so that group does not exist today.

Julie Cohn (00:12:00):

So, do you know when PG&E created the group and what their motivation was?

Alex Papalexopoulos (00:12:07):

Yes. The group was created—I joined the group, systems engineering group, in 1986, just when I got out of school. The group was created, I would say, three years earlier, I would say 1980, '83. So, I was one of the first. But then the group kept growing and growing. It had a lifespan all the way up to late '90. But then deregulation in California, which was the first market that deregulated the energy business, the energy sector, the group basically, people moved on, and all of them have actually just made great careers. Yeah, they have done great in the industry. So, it was a great group; we learned a lot.

Julie Cohn (00:13:01):

Why do you think PG&E chose to invest in that group in the early 1980s?

Alex Papalexopoulos (00:13:08):

I believe the main driver was a forward-looking CEO who wanted to develop internal expertise in various areas. And he thought a group like this would serve PG&E's interests very well. Back then, of course, we're solving different problems. Back then PG&E had problems with nuclear, nuclear issues. And there were a lot of regulatory issues. And the thinking was, if you develop a group like this, it will serve PG&E's interest in the long-term better.

Julie Cohn (00:13:52):

And they were unlike other utilities?

Alex Papalexopoulos (00:13:55):

Unlike other utilities. There is no question, unlike other utilities. So, I consider myself lucky that I found myself in the right place at the right time at the right age.

Julie Cohn (00:14:06):

And the software that your colleague developed that's still in use 30 years later, what did it address?

Alex Papalexopoulos (00:14:15):

Oh the software we developed at the time, as I was leading the group—and one of the softwares is related to predictions, short- or long-term, for the control center at the time—to forecast the needs of the California system, of the PG&E system, for the next five minutes, the next hour, the next day, the next month. And based on that, you are doing scheduling. That's how you schedule your generation. Remember back then it was a cost-plus system. It was not an open market with offers, bids, and ISOs. PG&E manages their own system with their own resources.

Julie Cohn (00:15:06):

So those timeframes—five minutes, an hour, a day, a month—they're very similar to the markets, at least in Texas, right?

Alex Papalexopoulos (00:15:15):

Oh, they are. Similar everywhere.

Jess Slater (00:15:17):

And is that because those were the increments of time that your group, or a group like yours, decided to use earlier, or—?

Alex Papalexopoulos (00:15:25):

That's a great question. The market design—for sure now, but even when we started—we tried the best we could to emulate real-time operations. The markets always need to support real-time operations. So, it's not accidental that we have a real-time market for five minutes, day-ahead market, and so on. Because basically we emulate how the operators operated the system for a long time. And that's what we start doing. And that's what we do even today. But of course, today there is a major issue that—I thought it would be out of business by now—that we have all these markets done, and that's it. We're back on the drawing board in some sense, because of decarbonization. The old conventional assets—fossil power plants, coal power plants, gas power plants, and so on—they are on the way to be replaced by renewable energy.

(00:16:43):

Renewable energy will be the dominant asset in the future. Which is good. It's clean. But for us, it creates huge problems, because it's weather sensitive. It's not like a gas. You have the fuel there that—

you're dispatchable and it's great. Renewable—I mean, you have solar when the sun shines, and when the wind blows for wind farms. And when these conditions don't pan out, you don't have the renewables you expect to have. And that's a huge problem. Today, for example, in Europe, the last two weeks, there's no wind. That's the weather. As a result, the renewable energy in the system has been diminished. As a result, you don't have enough generation. As a result, prices have gone through the roof. They're hitting the cap. So, we're moving to a weather-sensitive system, we need a new design, and we need new models and new software. And this has given us, boy, this will be going on and on for another, God knows when, another 10-20 years, I guess. So, our markets are in turmoil, basically, because the way we started the markets is for one simple reason: efficiency. Economic efficiency for operations and investments, that was the only objective.

(00:18:24):

Now we are asking for markets to do much more. For example, they need to deal with decarbonization. That's a huge objective. We're asking the markets to be fair, what we call energy democracy, because, as you decarbonize, we have seen that poor communities are being disadvantaged. So, there are policy objectives how to deal with that. Well, it's such a big objective to put on the markets. So, the markets today have to deal with many objectives we didn't have 20 years ago.

Julie Cohn (00:19:12):

Do you think that your approach to tackling that will be different in kind from the way you've done it for the last 30 years?

(00:19:20):

Absolutely. And the driver for this actually is not coming from the US. It's coming from Europe. The reason is that, as a result of the war in Ukraine, with the gas sanctions—the energy markets in Europe were designed—five, six markets in Europe—for several countries in Central Europe. In South Europe—they didn't have enough assets because of gas sanctions. The gas, the prices went so high in the trading floor, in the Dutch exchange. So, if the gas prices were so high, there was a domino effect in electricity prices that went very high. That created a huge political problem in Europe, because the model there is a little bit different than what we have here. It is closer to what happens in ERCOT: wholesale prices are reflected in the bills of end users.

(00:20:35):

So here you are, an Italian pensioner in Milan, you have a pension of 15,000 euro. You are getting a bill every month of a hundred euro, for your energy bill. And now you start getting bills, which, a thousand, every month, you cannot pay. So that created millions of delinquent accounts, millions—many companies went bankrupt. So, it became a huge political issue. And the governments intervened with subsidies, tried to support end users and small businesses. All countries, especially the south, Italy, Greece, Spain, Portugal, but even the north, Germany, they spent billions of dollars to subsidize the higher bills for their users, because the wholesale prices went very high. So, we have embarked on a major effort to redesign the market. Europeans call it market failure. I don't like the word "market failure," but in some sense it is a market failure.

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What do you do in those situations? Because we may have more of this in a renewable-based system. So, we are back on the designing phase to put new elements there, with emphasis now for consumer protection. Consumer protection becomes a big major objective of the new energy market design. Here also, we saw prices going up, but not much, maybe 10-15%. So, people didn't feel it because they pay the utility bill with the utility, and the utility absorbed that variation in the short term. In the long term, the utilities around the country, they go to the regulators, and they ask for an increase, but—so I expect prices will go higher here to end users but will not see the chaotic situation that we saw in Europe as a result of the energy crisis. Because here we don't really have an energy crisis. We have problems, but I don't think there is to a level to call them "energy crisis."

Jess Slater (00:23:02):

Dan, do you have any questions?

Dan Molzahn (00:23:06):

I have lots of questions. So, one is, I think the most relevant for what we've talked about so far is: you mentioned how policies, government policies, really affect the market design, especially in different countries. And I know one that—I think it was maybe you I was talking with about this previously—was about Germany, and how you had Western and Eastern Germany, and the Germans wanted to have one node in their systems so that you didn't get price differences between west and east. And that obviously has a really large impact on how you run a market, if you have everyone sort of participating as if there's one bus in the system. And so, I'm wondering if you could talk about that example or other examples of, maybe anecdotes of how policies and policymaker's choices have impacted the development of the markets that you've worked on?

Alex Papalexopoulos (00:24:02):

Sure. Great question, Dan. Let's start from California. Let's, I'll get to Germany, but let's start from here. California, we started a design that did not include the grid in the clearing. It's like trying to solve a transportation problem. You take into account the cars in the highway, but you don't take into account how many lanes you have, that you create congestion. The equivalent—all the markets in the US started from a zonal system, as we call it. California was three zones. The northern zone, central in central California, and then in the south, three zones. So, in other words, what happens within the zone, the markets have no visibility. In Northern California, there's one zone. What happens within the zone, the market operators don't see it when they run the market. The same thing was in Texas, and in the East. We thought, and this now turns to be an academic fallacy—

(00:25:23):

Excuse me, Dan. There was a professor from Harvard that told us it's okay, we may need to go in phase two on this. But the idea was to keep the market simple, simple enough for trades. Don't put all the physical constraints of a huge grid into the clearing. That was wrong. And in—for some people—some people believe, I happen to agree, but hesitantly, I have concerns that the energy crisis in California with Enron in 2000, 2001—one of the reasons of the crisis is this model. In other words, we didn't have visibility on an individual generator basis. We had visibility in three points: Northern, Central and South California. Traders are very smart people, and they took advantage of that, and they manipulated the market. That's the bottom line. And they extracted billions of dollars from the consumers. Okay? So clearly—and I have written extensively in support of the zonal model, but after so many years now, I know that those papers are not really useful.

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They are on the wrong side of history. Okay? So, we moved to nodal, meaning that FERC played a critical role, our federal regulator, for all markets to move to nodal. This started in the east and then slowly moved to the west. So, all the markets in the US are nodal markets, meaning, that when you clear the market, in addition to the offers—supply/demand, you have all the constraints of the grid. So, the problem is very complex now, as you understand. As a result of that, every node has a price. In other words, the price in Northern California is very different than the price in the LA Basin, and it should be different. So, there is huge price fragmentation, you can say, or differentiation, from node to node. Now, generators see those prices at their location, but it's a political issue to expose the loads to those prices.

(00:28:11):

And I remember back then, when we were designing the market in California, the mayor of San Francisco, the famous Willie Brown, probably, I don't know if the name, he sent a letter to the CEO of the Cal ISO, I saw, over his dead body, will allow nodal pricing for the citizens, ratepayers, of San Francisco. Why is that? Because San Francisco is an electric island, needs power from outside. It's an electric island. Because of these conditions, the prices in San Francisco are three times higher than the prices outside San Francisco. So, if we expose the ratepayers to prices, the true economic prices, the ratepayers should pay much more. Now, one can say, "Okay, the utility can develop hedging instruments, not to expose the retail ratepayers to those huge prices." The fact is that when we say "nodal," we mean, “for generators.” For loads, we have big zones that we socialize all the prices.

(00:29:28):

So, the price in San Francisco is the same price—let's say in Oakland, or in other places, but if you follow accurately the economic model, I need to pay much more. This is true everywhere. So that's California. ERCOT the same thing. Back in 2005, 2006, ERCOT moved to nodal. We moved to nodal the same way. The east moved a little earlier. But we have pretty much a similar model in the US. Europe will be the last continent to move to nodal. For example, markets we are designing now in Central and South America, they are all nodal; they really believe in the US model. But go tell this to the French or the Germans? No way. So, going back to the original question, Germany is a big country; there is one zone.

(00:30:30):

In other words, the price in Northern Germany that you have all the generation is the same with the price in Southern Germany, where there is all the load. But if you have no doubt, the price in the north should be half of the prices in the South. But this is part of the industrial policy of Germany, that basically they subsidize their industries. Because Germany is an export country, and all the business model they have as a country is exporting machines or exporting cars. So basically, they follow a very—they do their policies based on subsidies at the expense of residential customers. So that's a—that's going back to the politics policy. So, during the energy crisis, for example, if Germany had—no doubt, the model we have here, the prices in the north would be half of what they are now.

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

But so given that it's the biggest country in Europe, it has the—is the main driver of the economy. They have the most influence in the design of the rest of Europe. But if you talk to the neighbors, let's say, Czech Republic, Poland—we have designed a market in Poland. Poland, on the east, they have an enemy, Russia, and on the West, they have Germany that is very big on renewables, and they have offshore wind in North Sea. But as it comes down in the middle of the night, it does not go to south of Germany. It goes to Poland, because the grids are interconnected. And so, you have huge loop flows, and German power creates reliability problems for Poland. And the relationship is not very good, electrically speaking, not politically speaking, electrically speaking is not very good. So, they want to go nodal, but the Germans have an influence on them, and they try to slow them down.

([00:32:45](#)):

So, the same thing with the French. These two countries, I don't want to go too many technical details, given their geographical position, they take advantage of that. They rely on the neighbors to solve their security problems. And that makes their neighbors not very happy. Okay? So, I try to push the nodal model in the South. I have support for example, Italy. Italy has five zones, which is progress. Greece has one zone. We try to put two. And the Germans say, No. One zone. Spain and Portugal have one zone. They need to go to many more zones before they go to nodal. So that's where the policy and the regulation comes in. We take this as a given. They tell us, forget it, one zone, the whole country of Germany. And based on that, we built the models. But if they tell us, "Implement a US type of model with nodal"—a different regulation—then we do what we have done here in the US, which is a much more efficient model.

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

So that's where policy comes in. That policy is a big deal, is the most important thing in market design based on policy. We do our market design. And this is one area that clearly policy has a big impact on market design. There are many others too. For example, renewables. How you will pay for renewables. That's a major area that has to do with regulation. I believe now that we don't need to have subsidies for regulation for renewables. They can make it on their own. But every time we try to propose to treat them like everybody else, of course, you have strong lobbies from the renewable industry. Many of them have political influence. So, we still have some form of subsidies.

Jess Slater (00:34:59):

Dan, do you have any questions?

Dan Molzahn (00:34:59):

I've got lots of questions. That's super fascinating, Alex. I really appreciate it. And I know that's something we've chatted about a little bit before, but it's great to hear the more expanded answer. Another question that your discussion brings up is, so you had mentioned loop flow issues. And, going through, German wind through Poland, and same in France and their neighbors. So how do you explain this, what's really a pretty engineering technical concept of loop flows, or other related pretty technical concepts, to economists and policy makers and the folks that are making decisions about this? How does that go? How do those conversations go?

Alex Papalexopoulos (00:35:52):

The conversations here, you see, we are one country, so it's easier to have these discussions. And you have these forums with the federal regulators, who express our opinions. There's all the ISOs go to those who have meetings. We discuss it. Even though they have different interests, generators from the loads, nevertheless, the problems I see here, they are difficult, but they are not so intractable, like in Europe. In Europe, we need to go to the basics. Who is driving the bus? Whose influence really says that's what we'll do? In the US, the whole concept of opening markets came from industrial loads. This was a driving force in say, California. California has a nice climate, has good schools. Many companies like refineries, or PMW, or other big industrial loads, they were going to the governor.

(00:37:01):

They were saying: “We like California, we want to invest here, good schools, good people, diverse environment, but your prices are very high, so we'll go to Nebraska.” So that was the beginning of opening up the markets, the industrial loads. The industry was a driving force that influenced the political system and policies. In Europe, it's not the industrial loads, it's the traders. So, if you ask me who is the block of power that really influenced the politicians of the design, is the EFET, E-F-E-T, European Federation of Energy Traders. When I give presentations in a European setting, there are 200 people. I know very few. But I see the resistance in what I'm saying, from three tables down there; I don't even know who they are, but I know they are traders. I know they're traders, because other people come and tell me later—ISOs, TSOs, even regulators, the Italian regulator, the Beijing regulator: “Oh, we like that stuff, we need to implement the US model.”

(00:38:16):

But where is the problem? The traders. The traders, especially German traders that, they drive EFET, the European Federation for traders, are basically the block of power with most influence in the political system. And a US system is not perceived—that maximize their profits. Because if the whole country of Germany is on node, you can do a lot of games below their radar screen that are not visible to the operator. Here, we cannot do that. We have visibility to the lowest possible point. So, our markets are more robust. Clearly, you cannot make a killing as you—traders do in the European markets, but it's a much more sustainable market. So, this is one of the key reasons, I think, because they ask me, people know what is good. I mean, engineers, economists, academics, I talk to many European academics, they know that this model is the best. But when you go to the CO level, nothing goes in that level. They say, “Forget it, this is the model that is good for us.” So, it's an old boys' club. You can think of it that way.

Julie Cohn (00:39:46):

Do you think there's also a difference in sort of a longer historical culture of energy abundance and access to cheap energy here that was never the case in Europe?

Alex Papalexopoulos (00:40:05):

Not so much. Europe, especially Germany, who is the local locomotive of the economy, had access to very cheap resources for 30 years. The Russian gas, whole business model of the country of Germany exporting cheap products in the entire world, is cheap energy sources, basically, gas, oil through pipelines from Russia. But what happened two years ago, with the invasion, this world is over. Right now, Germany is in recession. Really. They need to change their business model. Now they suffer from lack of resources. They try to get resources from—expensive resources, like LNG, from the US; a lot of our gas goes through tankers to Germany and to Europe—they try to sign contracts with Norway and Qatar and Middle East and US, because they are now—they're lacking many resources; there's no question. But before the war, they had access to very cheap resources.

([00:41:24](#)):

Gazprom had basically conquered the entire Europe. I have gas producers in Greece who are my clients. Fifty percent of their gas comes from Gazprom. So, when the government said: "Stop it, we'll not buy anything, we have sanctions, we follow the sanctions," they didn't like that at all. They said: "We have very good relationship with Gazprom, we need our gas at those prices." So, they had long-term relationships with Russia, and it was a shock to all gas producers in all European countries to pull out from that model, from Russian gas. So now it's a different situation. I agree. But before the war, they had access to cheap resources, especially gas and oil.

Jess Slater ([00:42:16](#)):

Oh, yes. So, you were speaking about how like places like Greece and in Spain and Portugal, that they had one zone and they've been very defined in not wanting to expand that. Like in Italy that has five zones. And so, I'm curious, what role does public perception play in the development and acceptance of new markets? And what strategies do you think could be used to engage communities effectively to develop it to that; that you say would be better?

Alex Papalexopoulos ([00:42:42](#)):

Public perception, that's a big deal. Okay. Our markets—given the decarbonization efforts and the renewables and so on—our markets are under attack because they are not adjusting fast enough to the new energy mix. And we're trying very hard. We have many products in Europe, as I said before. Our new objective is customer protection, consumer protection. If the prices go very high, what do you do to develop activity rules to mitigate those high prices? So, the public perception is the following: Many places don't like nodal, because if they are in high congested areas, they will pay more. And they like a socialized bill that everybody pays the same, as long as they say you can implement anything you want, but I don't want to pay more. That's the key thing that I'm hearing from many public groups, because when we do market design, basically we have a stakeholder process, and everybody comes to speak.

(00:44:04):

It's a democratic process, but it's messy, because how you can compromise all these different views? But the fact is the public, especially in Europe, because prices are very, very high, it has become a huge political issue. And politicians, if I give you quotes from the prime minister of England, or the chancellor of Germany, you won't believe they start attacking the market design. And they know nothing about the market design, but they say: "Oh, it's the cause, why the prices are so high." Because really the political system and the consumers like markets when the price are low. When the prices are high, they don't like markets. But when the prices are high, they tell you something. They tell you that, there is a scarcity, there are problems, you need investments, but in our industry, the investments are long-term, cannot do it in six months or a year.

(00:45:14):

So, the current construct in some sense is under attack. Less here, more in Europe. But here too, we need to make changes to protect the consumers. That's the—so efficiency remains a goal, but energy fairness, it's also a very important goal. Just to tell you the impact of the energy crisis in Europe, it resulted in different governments. In elections with different governments. Sweden, socialist country for 50 years, they have an almost fascist government, far right party. Italy, the same way. And one of the reasons is the energy crisis. People say: "The system is not working for me." They start from inflation, high food prices, and next they go to high energy prices. These things go together. So, they say, in France, they had an election, the far-right party came first in the first round of elections.

(00:46:25):

Why? You ask the average French person will tell you, the system is not working for me. Inflation, food prices are so high, energy prices are so high. So, they put them together. So that's the perception of the public. So, we definitely need to do something. We have some ideas. We are—actually, I'm trying to present those ideas here too. Even though our markets are much more calm and they work as expected. But the day will come here too, that the bills will go much higher because of the decarbonization. Somebody has to pay for it; somebody has to pay that. We need to invest in infrastructure so much to bring renewables from Southwest to California. Now Europe is a much bigger problem: prices are much higher than they used to be, and people are complaining.

Jess Slater (00:47:31):

Do you have a question?

Babak Taheri (00:47:32):

Yes. So, you said the zonal model caused a problem in the US in early 2000, right?

Alex Papalexopoulos (00:47:38):

Yes.

Babak Taheri (00:47:38):

And that was the reason you moved to the nodal model?

Alex Papalexopoulos (00:47:41):

Yes.

Babak Taheri (00:47:42):

Is it possible it'll happen similarly in Europe, because they're already in the zonal model, like the said problem?

Alex Papalexopoulos (00:47:47):

Yes. On this side of the pond, we market designers were making bets when the European model will collapse. So far, it has not happened. It happened in California in 2000 with the Enron crisis. Why? We are always wondering why this does not happen in Europe. I think I have an explanation, I'm not a hundred percent sure, but clearly, if that model was here, it will be imploded in six months. The reason is that in the US we diversify our system, and we force utilities to sell their generation to traders at third party generation companies. In retrospect, if I retire, ever retire, I'm going to write a book, "Lessons Learned and Things to Avoid." Forcing utilities to sell their generation in order to reduce the market power to third parties, I think it's part of the problem.

(00:49:13):

In Europe, they didn't do that. It's the right thing to do to create competition, create many players. You force them to—like in PG&E, we solved all generation. That happens in the rest of the country. In retrospect, I don't propose this now to other countries. I want the utilities to stay the way they are and have other mechanisms to do market monitoring and monitor their behavior. Don't force them to sell their generation. So, in Europe, this has not happened. The short answer in my mind is that utilities have this sense that, of course, they want to make money, but because they are regulated—again an old boys club—they don't want to break the system. In other words, the market is gameable, but they don't game it too much.

(00:50:22):

Do you follow? If you have Enron in Europe, it will break the system in no time. But this is not happening. We see games, but they are manageable. And we don't see really taking advantage of those loopholes like our traders took advantage of our markets here in California, in Texas, in other places. That's how we move to nodal. Because here, if I'm a trader, it's my fiduciary responsibility to maximize my profit. And I treat energy like any other commodity like soybeans or tomatoes. Even though energy is not really soybeans. It affects the life of seniors or people, older people, poor communities. But our traders really treat energy like a commodity. Maybe you want to see that movie, "The Smartest Guys in the Room." Okay. There's a book on that too, with Enron. But in Europe, this is not happening because utilities maintain their structure. They are independent generators, but the utilities maintain the integrated structure, generation, transmission, demand, as an integrated utility. And that puts, puts the brakes of breaking the system. I don't know if that makes sense. But for many years, we're making bets in the highest level here among our designers, when the system will implode, because it's gameable. But it has not happened yet.

Jess Slater (00:52:08):

Dan, do you have any questions?

Dan Molzahn (00:52:09):

I always have more questions for Alex. One—I guess, follow up on this is, you seem very confident in the markets in the US? And yet there's still, as far as I understand, there's still differences in the modeling and market structures of how we do the market side of things. And then, you go talk with the operators—we were talking with some of the operators earlier today, and how , when there's problems, how they implement fixes doesn't always match what the market was doing—and so, I'm curious, is there just—maybe this is somewhat of a speculative question; I'll ask the historical question first—as you were thinking through the market design process, how did you identify which of those distinctions were sort of okay? The operators are going to do something, the market will do something else, but it's close enough, versus, this is something we really—obviously nodal prices were something that you identified as "this is really important to capture the physics very well," so how did you identify these are the pieces that we needed to model accurately? And these are the pieces that don't necessarily need to be brought into the markets at some level of detail?

Alex Papalexopoulos (00:53:33):

I still believe our markets are the most efficient ones, but because of the massive penetration of renewables, we have many problems in our markets too. But our problems are not deal breakers. We'll solve those problems. We have FERC. FERC has all these meetings. There is a process. We bring the problems to FERC. There are different associations. If you want me to kind of mention [a] few issues that I think require immediate attention for the security of the system, let's say, that the system doesn't break, is the real-time market. The real-time market that operators deal with on a day basis, a daily basis. It has problems. The problems start from the fact that renewables are so uncertain that when we clear the market 10 minutes before real time—in those 10 minutes, a lot of things can happen: uncertainty, forecast errors, cloud cover comes—the signal that has been sent to the generators does not reflect the minute-to-minute actual operation.

(00:54:50):

That deviation is getting bigger and bigger with the result that ISOs now, and utilities fail to meet NERC standards. Because those errors reflected what we call the ACE of the system, that should cross zero every 10 minutes. And ISOs are not able to do that. They are asking for NERC to relax those requirements. So, in real time, there is definitely a discrepancy between markets and operations. So, operators will do whatever they need to do to operate the system, and they will deviate from the market results. When markets deviate from operations, it's an issue of concern, because that's, to me, a metric of success: that the market should give you results that are consistent with the operations.

(00:56:04):

Because if the results are different, the operators will neglect the market results and do whatever they want to do, manually, to keep the lights on. So real-time operations is a big deal, is an issue that I have pointed in many forums that we need to deal with it. And we need to have a process. Even today, there was a market design committee that I brought up these problems, and we start their working group with different ISOs, to start kind of debating how to solve this problem. There are also problems with investments. The markets, even in the US, say, California, 2000 hours a year, prices are zero in the middle of the day. You have so much solar, solar is a zero marginal cost asset. So, the price of the market is zero, and then in the evening when solar goes away, the prices are very high at the cap, $200 from zero.

([00:57:11](#)):

Now if you have six hours, zero price, what does it do to gas producers that. They depend on that; that's their livelihood. So, there is a real problem with pricing, and we're going to keep gas for many years to come, because we need it as a transition fuel. It competes with solar, with batteries, and so on, but we need gas. But if eight hours a day, the prices are zero, we have done studies for gas producers that they're going to sell it because they cannot afford it. And then a hedge fund wants to buy it. And when we do simulations for the next 30 years, the money is not there. So, they say: “There's no sale, we're not buying.” So, we need to avoid that. And the solution to avoid that is to build better capacity markets. For example, ERCOT does not have a capacity market.

([00:58:12](#)):

ERCOT is—we designed the market in ERCOT. ERCOT is not under federal jurisdiction. It's the "Lone Star." It has its own PUC. They don't want a capacity market. And it's—they're very ideological about that. Texas is a very ideological state. They say: “We don't want a capacity market, that's state aid, our energy markets work well, we don't need the capacity market. Well, look what happened in February 21 with the polar vertex. What happened? The market collapsed for a week. So, do they need the capacity market? They do. But they still don't want a capacity market. So, capacity market, to me, second in the least, that we need to improve for investments that keep gas around for a long period of time. I would say 20, 30 years until we become a pure renewables-based system with batteries, and demand response, and so on.

([00:59:13](#)):

But for now, we need it. So, investments is a big issue. Do people invest in gas now? There are political issues. I don't see many investments. I see a lot of investments in the—close to the customer with rooftop solar, wind, batteries behind the meter. So, the action has moved with distributed energy resources close to the customer. So, distribution markets now become very important, but I still believe that we need to pay attention to the investment problem. And the third problem is infrastructure. The US system is very weak on grid investments. And there is a reason for that, because, for example, the utilities in Europe, they are state-owned. As state-owned, they invest, and they pass these dollars—<audible sneeze> Bless you. They pass this cost to the rate payers. Here, our utilities are private-owned companies, so they are very careful when they do investments; they're very careful.

(01:00:26):

So, we have advanced software to protect the system, and we put dollars on the ground for investments rarely. We have an optimal system, but we are always teetering at the end of the cliff. That's the thing. So, we're very good in software that—we're very good in methodologies, much ahead of Europeans. When Europeans have a problem, they do another investment. If you talk to the French, they will tell you, okay, if I need a good investment, I build another line. We don't do that here. We're very careful. And I think this has to do with the jurisdictional split between federal and state. Federal government, FERC can tell you, okay you get a permit to build a line. But it is the state that determines the cost, who pays, who are the beneficiaries. So, there is a jurisdictional split. And utilities are very careful how they navigate this complex regulatory construct.

(01:01:39):

And we don't see many lines going across states. Let's say I want to move—in other words, I want to build a highway system in the US for high-voltage transmission lines. But the way the politics work here, a city council member in a small town in Montana can stop a line that is good for the entire country. You know what I'm saying? So that's a jurisdictional split. So, this model that worked well for a hundred years in the US, with the state power of the states, encroachment of the federal government to the states, all this, it worked well for a hundred years, but now our problems are national, and I want the federal government to have more say in those investments. Because we need great investments. And if you look at every ISO, they have a huge budget for investments. Who is doing it? FERC is coming out with new orders about infrastructure. They came out with FERC Order 1920, and so on. But we'll see how it will work out. The point is infrastructure investment is a big deal in this country.

Julie Cohn (01:03:00):

If utilities are asking NERC to relax standards around ACE, what would that look like?

Alex Papalexopoulos (01:03:10):

Well, it's a great technical question. NERC has put those standards, so each ISO and balancing authority will not lean too much on the neighbors, right? They need to balance their own resources. So, they say this error—which is the frequency error at the interchange—error together make the ACE, it moves up and down, but it should cross zero at least once every 10 minutes, meaning you are balancing your resources. Right? Now, if we relax this, to me, it's already relaxed crossing zero every 10 minutes, it's already relaxed. Now, if you go to relax even further, that means we're moving into an unstable system where balancing authorities lean more and more on neighbors through interconnections. There is a point that this can create a domino effect. The system becomes more unstable, riskier to operate.

Julie Cohn (01:04:23):

Do you think it would open the door to more cascading failures?

Alex Papalexopoulos (01:04:26):

Yes. And we—I don't want to go there. All I'm saying is that we need to find solutions to those real problems. Right now, I know balancing authorities have a hard time meeting those NERC requirements.

And the key to all this, the problem, is the intermittency of renewables.

Jess Slater (01:04:49):

I had a quick question. Obviously, you've been speaking about this throughout the interview, but I wanted to ask more specifically, see how you would answer: what political, social, or economic factors do you consider the most critical in the decision-making processes for implementing renewables in today's markets?

Alex Papalexopoulos (01:05:06):

One thing that we want to do with renewables, first of all: get rid of the old regime with subsidies. Subsidies are contentious. The markets, some of these technologies are very mature and they can start on their own and compete like anybody else in a marketplace. One thing that I think is important that, we don't have much of it, is increase the number, develop the conditions for what we call PPAs between renewables, power purchase agreements, long-term power purchase agreements for 20 years with industrial loads, for example. So, if I'm a renewable investor, I can go to the bank, and let's say I'm going to finance my project. I have a 20-year contract with this refinery. So, I'm a big advocate of developing the market conditions to enable PPAs, physical and financial, between renewable investors and renewable owners with industrial loads. To some extent. This is happening with the big tech companies, Google, Amazon in California, and so on and so forth. But I want this to go all the way down to medium sized loads to have their own. And that's a great way to decarbonize the system, giving incentives now to renewables to have those deals so they can finance their projects. So that's an important policy objective.

Jess Slater (01:06:54):

Thank You. Do you have a question?

Babak Taheri (01:06:56):

Yes. So, you mentioned forecasting, and that was like causing a problem between the market and operation side. How do you see the impact of AI in markets, and if you're using it and—

Alex Papalexopoulos (01:07:09):

AI. Actually, I have been working on this through another company. I have—it's a controversial issue. From one perspective it's expected to solve many problems, forecasting problems, prediction problems, can do better diagnostics, improve maintenance, improve reliability. This is great. But there is another negative side to that. And the negative side is data centers. Data centers will prove to be one of the most intensive energy loads that we have. Those data centers that—you need to build AI with the microchips. These data centers will create huge energy problems. Now, in other words, the flat in the Western world—the consumption profile is pretty much flat. One percent. In the western world, there's not much increase of load. With AI, the expectation is that in the next 10 years, the load will skyrocket the demand. That will create problems for decarbonization. How we deal with data centers? I have mixed feelings about this. Who is building data centers? Google, Amazon, those type of companies, right? How they do it? They don't trust the utilities, they go now directly, they bypass the system, and they sign deals with nuclear power, as we speak.

(01:09:09):

I don't want to mention names, but one of these companies has signed a contract with a nuclear plant in the east, plant in the east, for 340 megawatts with provisions to expand to 900 megawatts. That's a huge power to serve the data center. It's clean energy, will feed only the data center. But where is the negative problem? By signing a contract, let's say Google, for a data center to get power from the specific nuclear plant, 900 megawatts, that means this nuclear plant is out of the market. What does it mean, it's out of the market? The prices will go up for the rest of the customers. So those companies, talking about energy fairness and energy democracy, decarbonization can work to the extent the prices stay affordable, the system stays reliable. If the prices go very high and people have blackouts, they will not go for decarbonization.

(01:10:19):

So, if I'm Google, and I have the deep pockets to sign bilateral contract with a nuclear power plant to get power for my energy needs of the data center, and I take that nuclear power plant out of the market, the rest of the market will suffer. Prices will go up. It will create scarcities. And in addition, Google, say—I use that name, but there are others—that they use the current infrastructure, that they avoid to pay what the rest of the people pay. There is something in the books right now. It may be public, but I don't want to go into more details. And we see more and more of these. I see the people who build the data centers to bypass the system and sign directly PPAs with nuclear power.

Babak Taheri (01:11:14):

Actually, that problem's already happening in the east. I know data centers is—right now, 8% increase of the load in Northern Virginia just because of data centers.

Alex Papalexopoulos (01:11:24):

Yeah, exactly. This will keep going up. So going back to AI, it's a blessing. It can solve many problems better than probably we can. It can help the markets and so on. But there is a negative side. The negative side is to build AI and build those data centers; the load will increase a lot. We don't know how our markets will react. And then on top of that, having these big companies taking nuclear power out of the market, that will disadvantage the rest in the market, because this is for them.

Jess Slater (01:12:01):

Dan, do you have any closing questions?

Dan Molzahn (01:12:03):

I actually have a follow up on this question. So, sort of more generally, AI is maybe—but wasn't—you had mentioned at the start you had done early work in AI and forecasting. Now we're seeing it come back around. But kind of more broadly, there's been huge innovations in computing technologies, in the ability to solve optimization problems, and optimization theory.

Alex Papalexopoulos (01:12:30):

Sure.

Dan Molzahn (01:12:30):

And mixed into linear programming solvers. And so, I guess my question is, how do you, or how have you seen both historically and looking forward how the different kind of computing technologies have enabled the development of markets? Have those gone hand-in-hand and—you talk about the folks at Gurobi, and they'll say these unit commitment problems are some of the hardest problems that they have to solve. So, I'm wondering how much has the electricity market development relied on these advances in computing and optimization technologies? And how much have the optimization technologies been driven by the needs of the market, or of electricity markets in particular?

Alex Papalexopoulos (01:13:11):

On the first part, in terms of technology and solutions, let's say Gurobi optimization methods, we depend on the software. Without that software, we'll never be able to solve the system we're solving today. For example, in California, our markets are daily. The day-ahead market has an hourly increment. You solve the problem for the next 24 hours. Now we are reducing that to 15 minutes. This means we multiply by four the computational complexity. Well, I can tell you ISOs are struggling to develop better and better software. Meaning the vendors, and meaning the three major vendors, Siemens, ABB and GE. How to deal with this? And we're working with those software vendors forever. They are really dependent on technologies like Gurobi to keep improving and do parallelization and virtualizations and all those things, because now we need [to be] faster and faster.

(01:14:21):

Furthermore, now we don't have only the short-term market problem for tomorrow and the next five minutes. We have the long-term problem, and we need to solve it for the next year, the next three years. And we need to have chronological simulations, every hour with full transmission in there. And then we're talking about a huge intractable optimization problem. And if you put stochastics on top of it, then it becomes almost impossible to solve. So, the answer is "yes, absolutely." We depend on improvements in optimization technologies. Basically 70% of our work is optimization. I mean, simply on top of Gurobi, we put the constraints of the physical system.

Dan Molzahn (01:15:09):

So, do you have examples of problems that you would've—I guess you've alluded to some of them, but I mean, are there anecdotes or stories about: We wanted to solve this problem and the solver's not there, so we did something else instead?

Alex Papalexopoulos (01:15:22):

Okay. Very simple. To solve the problem I mentioned earlier, in real time, when we diverge the market, the five-minute market, from operations because of errors in forecasting, renewables, and so on—one solution is to go from a five-minute interval—Europeans have a 15-minute market—wrong. We have a five-minute market because of technological limitations. I prefer to go to one minute interval. We can't, it's a technological problem. So, we are hitting the boundaries of where technology can take us. So, there is an ongoing struggle for optimization people to keep improving those technologies, because we need them, especially as a result of renewables now.

Dan Molzahn (01:16:15):

And do you have a sense of how much the—? These optimization companies have lots of customers, it's not just the electricity market says they are very important customers. But not the only customers, how important is that business to these solver companies?

Alex Papalexopoulos (01:16:32):

You mean like Gurobi?

Dan Molzahn (01:16:32):

ISO New England comes, knocks on the door, I suppose they're answering, is that right? Or?

Alex Papalexopoulos (01:16:36):

Oh, yeah. They will answer, but they have—. Usually how they work, they have a base product. If ISO New England wants something on top of it, then they work with them. But it's a slow process. It is not instant. It's a slow process. But those vendors I mentioned rely on companies like Gurobi to provide the kernel, the engine. Okay. So, it's an ongoing struggle, how to improve the technology. And it's, again, there are many problems we cannot solve because of lack of faster, faster optimization models. Now, AI maybe would be able to help us there, but again, I'm concerned about the negative aspects of that.

Jess Slater (01:17:23):

Thank you so much for spending time with us. We're going to wrap up with one last question. What advice would you give to incoming engineers or students to adapt to the evolving economic landscape of the power industry?

Alex Papalexopoulos (01:17:37):

This is such a great question. Sometimes, I give courses to universities. When I finish my PhD in Georgia Tech. I did not take even one course in economics. Even one. I learned it afterwards. Okay? So, for our engineers, I think it's important to expand their training at school and get a few economic classes to understand economics and financing. Okay? And also improve their project management skills. Engineers have this perception, I guess the public have this perception, or the utilities, or the management, that they're good in doing programs, but not to do advocacy. To put the engineer engineering in front of a regulatory environment. I face this problem once at PG&E, that I convince them as such, I can do—I can go to a regulator, and I can play advocacy role. So, there are two important skills that they need to get, in addition to the technical training you get, in order to become, well-rounded: financing, economics and project management to be able to play advocacy roles. Because if you are an engineer, you have a career path that stops somewhere. But if you have the other skills and you're a good engineer, the sky is the limit.

Jess Slater (01:19:24):

Wow. Thank you. It's a perfect end point.

Alex Papalexopoulos (01:19:28):

Alright. Thank you.

Jess Slater (01:19:29):

Thank you so much.

Alex Papalexopoulos (01:19:31):

Nice seeing you, Dan, even remotely. Fantastic. I appreciate your time. Alright. Thank you. Thank you. Hope I'll see you soon.

[End of interview]