Combustion Turbines/Combined Cycles

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Introduction by Charles M. Zeh: Our next presentation is by David Stephens of Florida Power and Light, Western Office. I think David is going to have a little different perspective here. Basically, his role and responsibility is on how to lower the overall costs of advanced combustion gas turbines.

Introduction

Chuck is correct that I have a slightly different perspective, but not quite the way he suspected. To prepare for my presentation today, I tried looking for a large electric utility dealing with these machines on a daily basis. I wanted to give a true user's perspective. Barry was talking about the market viewpoint — or how you look at market viability. He talked about the problems and issues in having these machines. I am a member of a group known as the Combustion and Turbine Operating Task Force. It represents primarily electric generators and utilizes the machines of all manufacturers. The group gets together twice a year and discusses operational maintenance issues. I interviewed these people. A synopsis of what they said could be, "I would really like to buy a H machine, but..." This is kind of it. From the user perspective, we refer to these machines as the H class, no matter who manufactures them.

First, a little bit on Florida Power Lights' experience. We bought the first four 501F machines. The setup is in our Lauderdale station, which went into service in the 1992-93 period. The setup is the first four-GE7FAs with the DNL2 system. In fact, we prototype the DNL2 system at that plant in the 1993 period. I was involved at the startup of the Westinghouse 501Fs. Once we put these in, we recognized that we had spent a lot of money on this system. In fact, an annualized buy for Florida Power Light for an entire fleet that includes some older generation simple bi-cycle units is $15 million a year. So my position was created to actually manage the life-cycle cost of these units for our corporation.

I will talk about the really desirable features of these systems from three viewpoints: technical, economic, and then some idea of the future requirements.

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[1] David Stephens was affiliated with Florida Power and Light at the time of this presentation.

Technical Issues

We have heard talk about 60-percent efficiency as a driver. It is, in fact, the largest cost. Operating a unit entails fuel consumed. Regulators are trying to get the best available control technologies. A turbine-inlet temperatures in the 2,600 to 2,750 °F range is required to get the 60-percent efficiency. That has caused these other issues to come into play down here — what I am calling closed-cooling and the coatings and single crystal areas.

In discussions, we call **closed cooling** mechanical integrity. This means the utility must assemble what many people call a Rube Goldberg of precise little pieces. And so you get bugs putting this stuff together. Operators are not really good at doing this stuff — they are really good at putting large parts together and hitting things with hammers. Now when you start looking at some of these designs, you are going to have to start putting together more precise little pieces. And they will have to stay together to keep the integrity of this closed-circuit cooling. So the concern is maintenance. And then, when you install these precise little pieces, how well are the parts going to hang together during operation, since this is a whole new feature that we have not seen before? The whole corrosion-erosion issue is a problem for the people looking at base and material impacts. Remember however, that we look at these things over a life cycle of a minimum 15 years, and what this means.

Contaminant deposition is another problem. When you are blowing air through holes, most of the contaminant go out the holes in an open circuit. However, when you look at some of these components over time, you find little nooks and crannies, especially with serpentine cooling, that tend to get deposits. This diminishes the ability to get the heat out of the blade. So this is another area where there is a some degree of concern in the user population looking at buying these machines.

The **coatings** issue is a major concern — especially robustness. Our experience has been that the coating systems available today are, in fact, the Achilles Heel of these components. It's not really coatings strength, because the coatings work well while in place. However, they are compromised through time — either through the loss of aluminum on the base coats or other effects.

Induced damage is part of the coatings issue. We have had examples with coating systems where the coatings actually damaged themselves. They became so brittle that they caused craze cracking, and the coatings spalled off way before we had a chance for the coating to actually fail.

The third part of the coatings issue is the cost to refurbish. As you get into more of the advanced coatings, this involves two areas. One is the removable aspect. You've got to make sure that the coatings can be completely removed easily in the repair cycle. Then you have the cost of reapplication of these coatings in the process.

The next issue is **single-crystal air foils**. There are a lot of concerns in a large-size manufacturing operation. This is the issue that often comes up in the engineering phase that is called the law of second- and third-order effects. Things that really don't matter on small scale really come into play in larger scale.

The relatively thinner walls in these air foils are a concern. The thin walls give you a lower area, and you lose the mechanical properties if they oxidize or have some other problem that you have played with before. Repairability is a major concern. We have directionally solidified components in one of our F machines. Initial repairs doing tip repair in a directionally solidified component were at 40 percent of the yield; now they are at about 70 percent. That type of yield really hurts the life-cycle cost to those who own and operate these machines.

Here is an example of the spallation of the coating. The failure of the coating occurred at 18,000 hours. Only two mechanisms could have made this happen. One was that this is on the section side just behind the leading edge. The coating got so brittle that it has fallen off. And the cooling system itself causes the area to overheat. We also found the machine to be slightly overpowered. We were getting better efficiency, but at a higher component temperature.

These are the types of problems that when you are putting in components and are expecting a 48,000 to 70,000 hour life in this component, then you pull it out. We had to pull this out early. I will say that the surveillance program was one element that helped, because we saw that the whole row was attempting to run hotter than we suspected. So it made us to kind of want to go into the machine and look at it. We did and we discovered this.

This transition duct is a common component. We have an ongoing problem with another machine where thermal growth is causing this transition duct to crack. We have yet to find a solution for fixing this. The OEM is working with this and is standing behind it, but is still having some availability issues for how to undo this thermal growth problem.

There are other issues — these are just examples of many things that are involved with this technology where there is concern about the degree to which they can be solved in the first units to be installed in the H-class machines.

Economic Issues

There really are three elements in the economic viewpoint: size and capacity, availability, and efficiency. The **capacity** or size we are really looking at is 400 to 500 MW. The introductory units are 400 to 420 MW in a combined-cycle mode. We think that can probably grow to 500 MW. Right now though, it seems that as the marketplace is becoming more competitive, not a lot of users can afford a 500 MW chunk of capacity. Or if they can afford it, their ankles are getting nibbled by all the shrews out there. We are starting to see 100, 150, and 200 MW chunks being grabbed by people getting in early smaller units. This is going to create more and more of a problem trying to aggregate demand to be at the larger level. We'll be better off if we can do this in the near term — I think it will be a lot more difficult in the future.

Retirement of old existing steam units will be the driver — replacing the "stranded assets" with capacities where you are going to have the greatest line share of being able to put these large increments out.

Distributed generation is a major issue. These are the gnats that chew on the ankles of the shrews. Distributed generation is going to be big. If you can get distributed gas and can keep gas at a reasonable price, efficiencies can come into scale. As Barry was eluding to his discussion, in this case, you can get a lot of the embedded costs of the grid not applying to the ultimate user. Remember that the ultimate user is paying for power at retail price. There is a lot of advantage to the ultimate user being able to get self-generated power. I can almost make this work within the Florida Power Light territory using existing technology with some customers that have some pretty dense loads. And I hate to think that if I started bringing in some of these 40-percent thermal efficiency machines (looking at 29 and 30 percent thermal-efficiency machines now), I will start taking away some of the FPL market.

Availability for these machines means, if it is available, it will run. These machines are truly base-load. However, what we are looking at is managing the outages. And management issues include cost, which comes down to life-cycle cost. That is driven by both the frequency and duration as well as the cost of the components themselves and their repairs. Another management issue is flexibility. This is really the flexibility in scheduling outages. Typically, you want planned outages in the spring and the fall because that is when you have lower demand. But you don't want to repair the entire fleet in the fall or the spring. So you often want the ability to defer unit repairs. If you are held to a very tight time frame in terms of when you actually have to do maintenance on a unit, some of the flexibility in scheduling is removed. So you try to design as much margin as possible into the components, and this becomes a technological problem. But you must consider designing enough flexibility to move outages around. You also must be concerned with the combustion turbine itself.

Efficiency is what got the machines on the table. That's why we're using these machines. That's driven by some gas price assumptions. The reason these are staying viable is the 350 to 400 million Btus. When you start getting above that, sometimes it's worth just selling the gas to someone else, and generating power with other assets. Volatility in gas prices is a concern. Volatility affects how one uses one technology versus another.

Gas availability also got the machines on the table. This is really two items — supply and delivery. One unique aspect in Florida is that we are right at the very end of the transmission grid. So we get all the liquids and everything else that everyone passes up. In fact, we have put gas heaters on both units. We just said the heck with it, and put heaters on the units to get past the problem. So part of the issue is supply side — or getting it there — as well as the delivery issue. And one of the issues that comes into play, considering where we are on the grid in this area, is that you will need auxiliary compression with these 30 atm compressors. That has to be calculated. That's why I asked the question earlier: have you calculated both your capital cost and your overall efficiency for running these units?

Future Requirements

So the next step is that we do need to get the machines in the field. So there will be a smaller and smaller population that will take the risk to deal with the failure mechanisms. You will find that it will be harder to sell the machines. We need to mature the design quickly. To do this requires a partnership of designers and manufacturers. And a really critical part of this scenario for me is the development of repair technologies. For example, I keep hearing over and over among the user population, "Are these real expensive single crystal components just throw away?" This just doesn’t fit right. The capital cost of those components versus the expected life and the comparability of any kind of damage really puts people off.

So the answer is simple — just give me a 75-percent thermally efficient machine, and we will be happy!