Sensitivity Analysis

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Just a couple of items is that the first presentation is a brief one on sensitivity and actually we've talked about it a little bit, we've had some offline discussions talking about it. And then the other one actually has more to do with mitigation of cable heating and what you can do correct a little bit of the experience I've had on that.

Temperature Rise

In the sensitivity analysis that, I think, is appropriate to do is put a lot of different variables that you have some control over, usually with underground cables is you're somewhat constrained over the amount of current that you're going to put on those cables and if you're designing then you have some control over the cross-sectional area of the cable and the construction of the cable and on the way those cables are placed in the conduit and the materials that are used around that. Part of what you do when you do this is, "What if? What if? How about this? How about that?" "Okay, what does it take to get me there?"

Some of the basic things, obviously, with electrical cables is the amount of heat that you put into the ground is proportional to the square of the current squared R and where that really has an impact is when you're having diurnal cycles. Or, for instance, the standard tables for cable ampasity assume at 75% load factor, which basically means that on average the electrical loading is 75% of whatever the peak is, and if you take that and square that, that drops you down to just about 50% so the fact is, for the standard tables that you're looking out for ampasity based on 75% load factor, that has about half the heat output of a cable at full load. So that's something you keep in mind when you're looking at this that as you look at the current occurrence. I should say the temperature of the cable or the temperature rise of the cable the heat generated in the cable, is going to be proportional to the square of the current. Other obvious things, the basic model is the more heat should try to get out, the greater the temperature rise, real simple.

One of the things I do when I'm trying to tweak the design a little bit is I look at basically the difference in the temperature between the cable and ambient and I know that if I have a certain amount of Q to dissipate is if I can do it, all I have to worry about is the Q and the ΔT because I have this effective resistance overall. That's what Neher-McGrath is all based on, the concept of this effective resistance between the cable and the ambient and it never quite works out exactly when you actually do the detailed modeling because it's not quite that nice but for some quick rules of thumb when you're looking at the model and you're trying to tweak things one way, you know, "How much current can I put through this cable? If I have a 65° C rise and I'm allowed a 70° C rise, then how much more current can I get into the cable?" Well it would probably be 70 divided by 65 to get my ratio but I have to take the square root of that because my current flow is going to have a squared impact on it. So if that's the case, if I have a cable running at 90 and above a 20° ambient, so I have a 70, and that's my design goal and the fact is I do some modeling and my cable happens to be 80, then I know that I can increase my heat output by that ratio but my current output is going to be according to that ratio.

So it's real simple math that you can do using the fundamentals just to kind of give yourself a reality check and come up with numbers and say really closely. There's a lot of times I'm asked off the cuff, I grab a table and it says, "Well what's the ampasity is 600 amps at a 75% load factor, what is going to be the ampasity of 100% load factor?" Well, okay, with just a little bit of math I can work it out.

FTB= Fluidized Thermal Backfill

So there are just some fundamental principles and these are things electrical engineers work with, I'm not sure thermal people. Fluidized Thermal Backfill; you know we have found that in most cases realistic dry soil is in the 200, maybe as high as 500, row range. I am always reluctant to believe numbers when I get them from the field when they've done an actual thermal dryout curve and they say, "Well the dry thermal resistivity is 150," and I go, "I want to see your data." If they come back and they say, "The dry thermal resistivity, and I'm in the desert, my thermal resistivity is 250." I go, "Okay, I accept that, that seems reasonable to me based on my experience." If they came back and said it was 500 I'd say ,"Oh, that's terrible where are you building? Is it in Eastern Washington?" I've been surprised in some cases, the actual thermal resistivity in the desert came in at, in the middle of sand in the middle of the desert, was like 175 dryout, but that was because it was very good quality quartz sand, very well graded so that it compacted nicely and we had good thermal conductivity.

And the other thing is, in my experience with fluidized backfill is, I've see a lot of different concrete mixers, they mix with fly ash in order to get the grading of the particulates because what you really want is something with a minimal water that's fluidic and no air, absolutely no air. I've had contractors come and say, "Well here's our standard mix." I'll read the mix and it says, "Air entrainment additive," and I go, "Wait a minute guy, you're putting an air entrainment additive in a fluidized thermal backfill? So you're basically going to fluff this stuff up and make it full of air?" For concrete, that's used in a building, that's a great idea because it gives you some better thermal expansion and contraction capable properties, it's wonderful, but in a fluidized thermal backfill, it was a terrible idea.

But we have found, in general, getting the thermal dry resistivity of a fluidized thermal backfill below 100, is a challenge. I have seen them come test out below that but it's very rare. I've had other people come in and say, "This is my awesome mix and we test it and it's 150 or 125 or 110. (Audience comments) I do not know the gruesome details about how that is done but my understanding is that the concrete is actually baked in an oven at elevated temperatures for a week in order to basically drive out the moisture. I guess my feeling is if it was baked in an oven at 90° C, that's realistic, because it's going to be run that way. (Audience comments) The question is how much heat are you putting into this concrete mix, this fluidized backfill, you're drawing it out because you're putting its source of heat in the middle of it. (Audience comments) I agree with you totally, which is because you have moisture in it and because it is actually foundation concrete and it hasn't been heated. But the assumption is that with concrete used in an electrical ductwork, you have a source of heat inside that runs, theoretically if it's a data center, 24/7 baking that out day after day after day.

So the question really goes is; once that has been in there and operating for a year or two or three years, what is the thermal resistivity of that concrete? Has it crept up? And so as a designer I'm looking at something this is going to have a 20-year design life. If I was a utility I would have a 30 to 40 year design life, but as for things like wind projects of photovoltaic projects, they pretty much assume after 20 years the equipment is scrap and everything is going away so we design for a 20 year lifetime. So you still have to think about over 20 years, "Where is it going to be?" (Audience comments) I'm not going to argue with you, there are trade-offs, so I will absolutely agree with you and there are some times where I look at this in the thermal resistivity and what the switch gear is trying to pack and what we're trying to squeeze in and what happens in a lot of cases, you actually have a few benefits as you can get some convective cooling in ductwork that you can take advantage of and I'll touch on some of that a little bit later. But we actually did that at the Stateline wind project when we were melting cables down, we had most of the cable direct buried but we had some in conduit and we never had evidence of overheating of the cables in conduit, never. And we figured, on the other hand, is this is basically a conduit running from a vault to a riser and it's ventilated on both ends and we had heat transfer going on and we figured, "Well it's not a lot but it's enough." It was enough to give us the benefit.

ICEA Ideal

This is some calculation that I was running; we were looking at the sensitivity analysis. Here is the ideal case with 90 row soils, a little bit hotter ambient temperature, 30 instead of 20, design 90° C. According to this you should be able to pack 622 amps in it, in a row. And that is the density of roughly 50,000 W per cubic meter for the conductor.

300 Rho Soils

When you kick that up to 300 Rho soil, it didn't work so well and in fact this is the model that the picture there's actually showing with fluidized backfill, but I lost instead of 622 I was down at 368 and then the question is; what happens if I throw some enhanced thermal backfill in. I'm actually able to recover this kind of the configuration, not this is a relatively high block close to the surface, but you look at the amount of heat flux going straight up out of that and I'm able to get it up to 417.

Add 100 Rho FTB

And actually this is an indication of the kind of the pipe connectors, only this actually brings up almost to the service and I'm able to recover quite a bit of ampasity but because I'm in 300 row native I can never get up to my 622. Again, this is assuming dry conditions and this is what I'm working with. So this is where I was actually able to play with the design of the fluidized thermal backfill and how much to put in to find out what it would take to get me there. (Audience comments) Actually those discussions have been broached with owners and developers, in the case of Eastern Washington, the basic comment is we don't have water rights so there would be no water available for them to use in the first place and the other one is; the near building is a maintenance nightmare inside because you're looking at a seeping system. (Audience comments) As I'm looking at things like photovoltaic project in Palm Desert or a wind project in Eastern Washington, where the cost of the system plus the maintainability and the reliability and when it fails what are the consequences of that? And the difficulty is that you're shifting a capital investment to a maintenance costs and then that has an ongoing cost and usually developers and owners don't like to do that because they don't want to in curse those maintenance costs.

Summary

So, basically on sensitivity analysis there are a lot of things you can do with the impacts of ambient temperature, you can play with the thermal resistance of fluidized backfill, you can play with the size of fluidized backfill, the whole issue in this case was, "how close to the surface do I bring my fluidized backfill?" you know, I can basically move it up higher and higher to the surface and see what impact it has and you know, obviously, you are putting more in there, it costs more money, but you can at least see what the thermal benefits might be of that by incrementally doing a sensitivity study. (Referring back to slide 300 Rho Soils) I talked about this earlier, is that when you have two parallel cables you can change the spacing on those cables and find out what happens and iterate, or you can see what the impact of the thermal resistivity of the material might be. What if I assume I have lower thermal resistant soils or backfill, what's going to happen? When I've done analysis using cable and conduit, I will always vary the thermal conductivity of the air between those to determine what impact that has because that's so poorly defined in such a convoluted and complex analysis for those, that convection radiation conduction, is I will take a range of values and look at what the impact might be, normally I find the impact is not major, it's not a significant issue so it kind of falls out that I pick a mid range value that makes me feel comfortable that I feel is giving me representative values. (Back to Summary) So my argument; you cannot assume wet soils, well I guess if you can, irrigate, you can do that. Well, and what I also say, add cable temperature monitoring with the advent of fiber-optic cable temperature monitoring, especially in high-voltage cables where you're spending a small fortune on the cable and the duct bank, is it is now standard practice to include fiber-optic temperature monitoring, either in a separate conduit in the duct bank or you can actually get the fibers embedded in the cable. I have seen designs where the fibers are actually in the center of the cable, you know you'll have a conductor that's made up of segments and conductors, instead of having one wire in there there's a tube inside that with fiber-optic cable. I've also seen it done that instead of being embedded in the high-voltage portion; it's embedded in a wire, one of the concentric neutral wires around the perimeter. So, again, it's a surrogate, it gives you a temperature indication as to what's going on in the center conductor and what's happening with your cable. But the nice part about it is it gives you real-time monitoring so you can actually monitor the temperature of a cable in real time and if you do start to have problems like they had in Auckland with dry out and the temperature cable starts to get hot, you'll be able to know. And I see that as standard practice right now and all the installations that we're seeing at anything at 115 KB and above, 230, 345, 500. (Audience comments) The problem that we found with that, actually I had a pipe type cable buried about 6 or 8 feet now and I wanted to RTD's on to just monitor the temperature of the cable because we had no clue as to what was going on with this cable. And the process of excavating down to expose the cable and mounting an RTD to the cable and bringing the RTD leads back up to the surface was incredibly labor-intensive because we were talking below ocean depths that require shoring to be able to access this existing pipe type cable and then we actually had, I mean we may have to deal with the installers, but we're really trying to be really careful, we had a 50% failure rate at every place we put our RTD we always put two because I didn't have a lot of confidence in the reliability and within about a year 50% failure rate, I don't know whether it was because the RTDs failed or the splices failed or they corroded or whatever, but there were a lot of issues with that, it could have been moisture, exactly. Well this was actually down in the San Francisco Bay so we were below the water table in a lot of places place, so that could be. But regardless, that's one of the issues from a utility standpoint is that you want something that's very robust, that does not require calibration, does not require replacement, has got a good track record and basically is going to run forever and is easy to interface and the bottom line for mutualism perspective is the temperature. I need to know the temperature of my cable, if the moisture goes away and I'm not running any power through the cable, I don't care. If there's a lot of moisture and I'm running a lot of power and the cable gets hot, I care. So what I really care about is the temperature of the cable, not the moisture because it's the effect that I'm going to worry about, that's what's going to degrade the cable is the temperature. So I've never heard of anybody putting moisture sensors in. (Audience comments)

Presentation 5b - Getting the Most from the Cable

We don't know if it can and part of it was a combination of things as those cables that installed temperature sensors, those temperature sensors were installed after we had failures and we learned what we had done wrong and we actually then went in and did "mitigation" so those were after the cables were cross bonded so we reduce the heat output dramatically so they were going to run much cooler and also, in places where we were able to get good compaction because there were accessible locations near the substation, not up on the side of the hill where we couldn't get the compaction in the first place. So the soil was probably slightly different in our care and installing it was different and the conditions were different so yes, absolutely, we never saw anything like that in the 90 degrees.

Approaches

We touched on the little things but I wanted to do a little brief presentation about some of the lessons we learned when we tried to solve the problem because at least in medium voltage and high voltage power cables not really 600 volt below. There are some things that you can do to reduce, to basically get as much thermal capacity out of the cables as possible and in particular, there are cross bonding; cross bonding is basically wiring the concentric neutrals of a cable in a fashion that I have diagram that canceled blocks the current flow on the neutral and we did that for Stateline where it's been done in other projects, as well. It's the normal practice on high-voltage power cables, when you have high-voltage power cables 115 KB and above, they are normally cross-bonded; you can increase the resistance of the shield. What happens when you get the magnetic coupling is you get a voltage induced and the amount of power is going to be V^2 over R so the higher you can make R the lower power dissipation you get.

So if you have a very large concentric neutral, you're going to get a current and more heat dissipation in that concentric neutral; by going with less neutral wires or a tape shield or something of that nature, you can increase the effective resistance, not the voltage, but the effective resistance and reduce the amount of heat power that's being dissipated. You can go to open Shield Operation, which basically means instead of creating a loop that the current can flow through on the neutral, you open the circuit and block any current flow. And then what I call cable arrangement is tray foil versus flat, single cables and ducks, a lot of other things. Then, obviously, we've talked thermal backfill, natural errors, circular enforce and actually there are installations where forced air circulation is used and those are often found in power plants where you have a large tunnel with multiple high-voltage cables in it and they will basically just blow air through it. But that's a controlled air fill environment where you have constant maintenance and that has a lot to do things.

Cross Bonding

Gaylon, this tries to explain your question, you said you don't understand how cross-bonding works and so I drew another copy of that here and wherever you access the cables, the concentric neutrals, which are the outer ones, have to be bonded to earth for safety reasons. And your power conductors are green, your red, your blue; and those are obviously insulated and operating in high voltage inaccessible but the neutral conductors are normally grounded and the problem it that if you just connect neutral to neutral through on both ends, you're going to get all kinds of current induced on that and one way to think of it is you get I, IX, IX, here, is the voltage is induced on these and those all happen to be in phase so I mean that's the current flow you're going to get because the magnetic field that is inducing this voltage and the resulting current on this concentric neutral is caused by all three-phase conductors and it's always going to be in the same vector arrangements, it's always got to be going in the same direction and that's what cross-bonding does, is it actually breaks the concentric neutrals into pieces so that the voltage that's induced on this concentric neutral is here and then it's here and then it's here (Demonstrated on whiteboard) and because this is a three-phase system with the currents 120 degrees out of phase, the voltages that are induced and 120° out of phase from each other and as a result you basically get a triangle when I had from ground through VA, then VB and VC.

The essence is that the three voltages are connected in such a fashion that the net voltage across here is minimized and ideally if this segment of wire is exactly 1/3, 1/3, 1/3 then the voltage induced here, here and here are exactly the same and that assumes the physical geometry between the cables is the same, the current and the conductors is the same, the spacing is the same; that what'll happen is this resulting voltage at this point is in essence zero. So between my two ground wires on the opposite ends, this is all insulated in here, I have no voltage. And if I have no voltage along my wire, I have nothing to force current flow so I can basically eliminate the current flow that would normally flow on this concentric neutral because of that induced voltage to zero. Now, a problem with cross bonding is because these joints have to be insulated, the conductors between these neutrals have to be insulated, and you also typically have surge arresters installed at those points and they have what they call a link box which is the box that they use for making up all of these connections and that all costs money. However, this is the standard practice on high-voltage cables where they do cross bonding because the cost of the link box and the cross bonding is insignificant relative to the cost of the cable. When you're dealing with a 12 KV installation that might be on the streets here oh, that would be terribly expensive relative to the cost of cable, so you don't do it.

Well we found that with 35 KV cable it's kind of a never never land between the two; where in some cases it makes sense, in some cases it doesn't. Where you have a problem with induced current and you have existing cables and have to physically have the cables apart, you cant fix that, then the solution is to install cross bonding because you only need to access the cable occasionally. So if this is 5 miles, all I have to do is come up with two points and make some modifications to the three cables at those points, only to the concentric neutrals at those three points and by accessing those cables, exposing them and cutting the concentric neutrals and wiring them up differently I can actually get a pretty effective cancelation and some good neutral current control. But in 5 miles of cable, and actually what we found was you're going to have splices anywhere so what we ended up doing is going back where we had splices already and just reworking the splices. And you're not changing the energized conductor; you're only changing the way the neutral conductors are connected, the neutral connectors together. And normally what you would have, if you have all of these bonded together, in a conventional install that's connected there and these are all connected to a ground rod, that's what you normally do. So what you do is you remove the ground rod, you cut the connections between all of these wires and you insulate those connections and you run them into a link box in order to do cross bonding. So it's relatively cost-effective way to fix a problem.

Link Boxes

Here is another example; a picture of what the link boxes look like, these are surge arresters here and basically here are you splices and you just bring your six wires from your various concentric neutrals into this little aboveground box and it has all these connections in it and you just wire it up and run with it. So that's one way you can get some more capacity.

Increase Shield Resistance

Increasing the shield resistance; so basically the heat loss is proportional to the square of the induced voltage divided by the resistance. If I can't fix the induced voltage I can design with a different resistance so we can go to a smaller shield conductor or a tape shield and the limiting factor on that is what the available fault current is because in an electrical system if you have a fault someplace out 5 miles away the fault current leaves the energized conductor and has to return through a grounded conductor to come back to the substation. Well that means you're grounded conductor has to have the same current handling capability as your phase conductor, at least as far as the duration of the fault occurs. So a typical large wind project might have 25,000 amps of available fault current at 35,000 volts and a typical circuit breaker clearing time might be six cycles, 1/10th of a second, so there has to be adequate tape survive, without failure, that kind of event. So there are some limiting factors as to how far you can go with that and what typically is done to make sure you have a really good high current ground return path so to try to basically protect the tape shield from damage is you put a separate ground conductor in, when we first started doing this we used copper and then when we were in environments where you don't have a lot of moisture the center practice is to actually use copper weld which is a 40% copper coating over it, basically copper sheet on a steel conductor. It's a lot cheaper, it has no scrap value, so you're not going to have to worry about someone stealing it and it's totally adequate for the function, it will not corrode in the 20 year lifetime of the project; so the separate ground return conductors pretty normal.

Open-Shield Operation

The other option you can do is you can get into open shield operation and I've actually done this in a couple of cases. We did this on one project, one of the feeders at Stateline. The limiting factor is that you have to calculate the voltage during a faulting condition when you have a really high current because you're going to get a voltage rise and you don't want to have the jacket of the cable fail; the jacket is typically insulated by about 10,000 Volts so when you have 25,000 amps of current you have a huge voltage rise, you have to calculate out with the jacket voltages and that tells you that as long as you get low enough you can get away with open shield operations so you basically have cut open the circuit, you have broken your underground service so you can gain back the capacity.

Cable Configuration

Cable configuration is the other item, is when you're putting the cables in the ground and they're spaced apart there is more current flow on the concentric neutral if you have it, and this is very interesting, this is out of an Okonite manual that I scanned and this is their ampasity table and recommended install and very carefully it says "Open circuited Shield operation". Except I can guarantee you that anybody that looked at that manual probably had no clue what that meant and just looked at the ampasity tables and grabbed the number. Whereas, for this trifold triplex shields bonded and grounded at multiple points. Now, the trade-off you're dealing with is thermally this is wonderful because the conductors are spaced apart; you have more area to dissipate the heat. In this case, all the conductors are in a very tight group, you have more heat. The disadvantage is you have to put cross bonding in; it costs money. This, you don't have to put cross bonding in, so what we're finding is that in most cases this is what's going into ground these days because it avoids all the issues of cross bonding. You still sacrifice some current carrying capacity because there is some current on the shield or on the concentric neutral and you have to design for that; but, because you avoid all of the cross bonding and the cross associated with it, that's considered a preferred approach.

Thermal Backfill

Thermal Backfill we talked a little bit about it, this happens to be a recipe for one particular mix, this is actually Palmdale which would have been a wind turbine job down in the Tehachapi's, I think is probably where this was, and this was their mix in order to get and actually I'm in thermal resistivity at 10%, moisture content 38; but, dry 105. And one of the biggest challenge that we've actually had with this is getting the fly ash because that has to be shipped in from a coal-fired power plant and because that's one of the critical ingredients, even though it's not a major portion of the overall mix, it's still enough because what you're using is incredibly particular dust of fly ash to basically make a graded mix so that you have a minimum amount of air entrainment and a maximum contact between particles to get the best heat transfer coefficient and we've had people come back with other mixes that they're proposing and they'll say, "Well, we cant get the fly ash, or the fly ash is too expensive," and we'll propose doing this and we say, "Fine." And they test; well they can't get down this low because those are actual test results. And I agree with you Gaylon, what is the thermal resistivity to design to, 38 or 105? (Audience comments) How often does this project run? 24/7? Data center? And what's the guarantee that there's going to be moisture in there? In that case I would say where are you and what is the rainfall pattern look like and are you sure there hasn't been a drought?

So, again, basically what you're doing is you're looking at a probabilistic model in your mind. It's like, well what are the odds of this and do I want 2 to 1 safety factor or a 10% safety factor or do I not care, I'll go with a -10% safety factor because I've overdesigned it everywhere else? And to me, that's what engineers do is; you never have enough data to make a decision that is perfect so all you can do is you can make the best decision available with the data you have. And that's one of the biggest differences between a scientist; a scientist wants all of the date and will dig and test and research and get all of the data and then draw conclusions from that data; and engineer has a job to do, he has to get this thing built and he knows he's never going to have the data so you just go with the best shot you've got and you end up being conservative. You overbuild it, if you're NEC you add 25% to the ampasity and then you de-rate the wire to a lower temperature and you do something with the load factor because you know you're going to tweak it a little bit there and you've basically built in several protective margins and you go, "Look, I can spend another hundred thousand dollars on a research paper on this or you can go with this and get the job built." And to me that's what an engineer has to do; you just have to move ahead.

FTB Performance

And that actually was a dryout curve for that FTB. (Audience comments) In that case, it's a trade-off between getting an answer quickly and the fact is that we all know that concrete continues harden over time because the hydration process continues, native moisture migrates in and the crystals keep growing and the concrete gets harder and harder over time. And yes, so I mean it's not a perfect science so you're absolutely right.

Natural Air Circulation

And the other one was natural air circulation; this was actually the Stateline project. We had some cables in and the fact of the matter was well the conduits came from one end to the other end and we just left both ends of the conduit opened and we found that because this is a wind project, that the only time power flows is when there's wind and when there is wind you get air circulation through these conduits and even if not a lot, we never try to measure it, we never try to be analytic about it, but we did find that we never saw any evidence of overheating of the cables in conduit and we surmised that that wasn't a bad thing because we didn't have to fix that cable and it was probably because there was just enough heat transfer through the convection in there to get us that little bit of extra heat out of there.

Forced Cooling

Forced Cooling has been done, I've see it done. Forced oil circulation is done on pipe type cables, these are pressurized cables filled with oil and there have been a lot of papers available on that. Pipe type cables are out of favor, simply because there were expensive and high maintenance and I don't think you'll see any of them in the future but that's a possibility. Forced air in conduits; I've seen papers on it; I don't think anybody's done it. Actually I did read an article, not that long ago, about it. There was a project somewhere where they had tunnels and they had a utility tunnel with high-voltage cables on the walls and they actually had a building on one end of this to basically blow air, they pressurized the tunnel and blew air through the tunnel in order provide some additional cooling for the cables. The other advantage is it would make it a tolerable working environment for the people that have to go and inspect those cables because if you think about the cables, they are happy operating at 90° C. so that could easily be at 60° C. and that would be a pretty miserable place to have to go if you're a worker. I've actually been down in steam tunnels underground and that's a miserable place to go. University of Oregon was terrible down in the steam tunnels.

Monitoring

Monitoring; a couple ideas, again, primarily for high-voltage cables, fiber optic monitoring, it's a distributed temperature sensor. I don't remember the physics, and someone please correct me, but it relies on the change in the refraction index of the fiber as a function of temperature and by basically pulsing the fiber is they actually can look at the reflections from the change in refraction index and build up a temperature variation over it with that. To me, I don't have it that's magic but it works and it is a very slow process because of the fact that the signal that is reflected back is at such a low magnitude that it takes many samples to be able to pulse the entire length of the fiber and so it's not unusual for it to take several minutes to actually build up a temperature profile along a kilometer of fiber, even though the light is traveling at the speed of light but it's just is part of the process of getting the data extracted from it takes quite a bit of time.

On the other hand is you're looking at thermal issues in underground cables which are relatively slow events so if it takes an hour to get a temperature profile it's usually not a big deal. (Audience comments) Utility is going to take that data and basically find that maximum point on it and that's going to be flagged off on an operators terminal and it's going to turn red if it gets above a certain point, or yellow if it gets above a certain temperature, red if it gets above that temperature and then it will start blinking if it gets even higher. That's going to be the operator interface and the bells go off if it gets really high. (Audience comments) Absolutely, and you don't know what the cause is, and it may have nothing to do with drying, it could be loading; you could be running this thing in an emergency operating condition, you can have a failure in the cable, too. And then you can do spot monitoring. The spot monitoring, however, is what we did at the Stateline project, we just basically put a temperature sensor in at a location and said "well we have no clue as to whether this is anything other than just representative, we don't know anything about the soil thermal characteristics, we don't know anything about the Ambien, but it least it will allow us to develop some characteristics and we gathered some data basically looking at the loading of the cable versus the temperature of the jacket on the outside of the cable and it followed beautiful as the loading went up, temperature went up evening out of the temperature; it was exactly the kind of thermal characteristics you would look for. And it was interesting is that if that's the only thing you have; if you have ambient temperature, jacket temperature and load, you can actually then back calculate a hypothetical effective thermal resistance all in Neher-McGrath. I have point A, I point B, I know what the Q is at this point, I got my two temperatures, and I can calculate my effective thermal resistance. So there are some things you can do.

Summary

Basically, if you're trying to get the most out of your underground power cables you reduce the parasitic heating and you improve the heat dissipation doing whatever you have to do.