Chris Rutledge

DYNAMIC RATINGS

Interview with **Chris Rutledge**

Product Engineer
at Dynamic Ratings

> “To maintain the breaker properly, you need to exercise those breakers every year. The longer a breaker just sits there, the more likely it is to fail.

Photo: Dynamic Ratings

In this interview we talked to Chris Rutledge, the Product Manager of the Breaker Division of Dynamic Ratings. As we launch Power Systems Technology and look out for experts in different areas outside the transformer, Chris is a perfect person and an expert to talk to.

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Alan Ross: Chris, I would like to call you our in-house expert on breakers, monitoring, maintenance, and all things breakers. Thank you for joining us.

Chris Rutledge: Thank you, Alan.

AR I am really passionate about the reliability of the system as opposed to the reliability of assets, because I'm a reliability guy. And the IEEE Reliability Society, which I'm a member of, focuses on components of an asset; they don't even focus on the assets in the system. I know that you find this familiar because you've been in the transformer industry and you understand transformers. You have worked for Memphis Light, Gas and Water (MLGW) and you've been around the industry as a practitioner. How long is your experience?

CR It spent about 27 and a half years at MLGW, and I am running close to three years at Dynamic Ratings now.

AR Let us first get down to basics here. One of the things that strikes me about you is that, like me, you are also someone who likes to look at the reliability of a system. But I want to talk specifically about breakers for a moment and the impact on transformers. When you are looking at breaker maintenance and monitoring, you are talking about backup in the system, etc. What do you think the negative impact is and in what way it could be positive?

CR It's really a huge thing if you think about your substation and just your general layout. Let's take a distribution substation, for example. We have a lot of feeder breakers that feed individual circuits going out to the customer. We have a bank breaker between the transformer and the feeders. So, if a feeder fails to clear a fault, that bank breaker is now going to operate and you're going to kill the whole bus. And then of course, we have our high-side breaker which is going to kill everything that is a fault and comes from the high-side or if that feeder fails to clear. And I've seen instances of all of this. I think what a lot of people fail to notice is the effect that those breakers are having on that transformer. When it comes down to it, you have your relaying but those breakers are your sole source of protection for that transformer. There is nothing else to interrupt a fault current coming through there except that breaker.

And I have seen in my career, I think, three failures associated with breakers that did not open.

If you have a low-side bus somewhere between a bank breaker and transformer, the high-side breaker fails to open and the breaker fail scheme doesn't work, you end up with six minutes off through fault on a transformer, which is a catastrophic failure every time. Not only that, but the amount of damage done to the station is large. When a fault hits the cable trays after it has burned all the grounds off, it burns the station house down too. So now, we can't bring that transformer back online, but we're also stuck with two other transformers we can't energize because we no longer have any control in the station. That's a worst-case scenario for breakers. What I've really been concentrating on lately, is helping people to understand how that scheme works. For instance, that feeder breaker sees that through fault, and let's say we're at three cycles for our feeders. That transformer immediately sees that fault as well. So, the whole time that fault is present, it's going through everything in that series circuit from that feeder. So, you are feeding it through the whole time.

When I was working with utility, I found that we had a lot of slow feeder breakers. Let's take for example first trip testing. For years we were going with offline timing and travel. You have to operate the breaker first to run that test. Here already you've lost a wealth of data as to how that breaker is going to perform once you do that first operation. But where you really get in trouble with, and the part that is getting overlooked by a lot of utilities I feel, is when that feeder breaker clears. You have some delay between the feeder breaker and the bank breaker. Let's say it is a 15 cycle, which means that that bank breaker has given that feeder breaker 15 cycles to clear that fault. Let's suppose we have a feeder breaker that clears in twelve cycles as opposed to three. That's four times the duration of fault current we should be seeing on that transformer every time that happens with that particular feeder. As that fault is going through that transformer, you have to understand that there's mechanical stress that is caused by the fault current. So, we've got radial and axial movement of those windings when that fault is going through. But the second thing you have to consider is the thermal stress that's placed on the transformer. So, the longer that feeder breaker takes to clear that fault, the worse that thermal stress gets, the hotter it gets. And that's exactly what you are doing to all your insulation systems and that transformer with that short being held longer than it should. So, you are destroying some of your solid insulation or excessive amounts of solid insulation every time this happens. That transformer is sent out of the factory with a certain amount of clamping force on that core coil. But that's dependent on the mass that you're clamping. So, as you are thermally degrading the cellulose insulation system, you're essentially taking some of the mass away from that core coil and now the clamping force isn't what it was when that transform was shipped out. As this goes on, over time you are losing clamping pressure, which is now allowing for more axial and radial movement every time we have a fault. This is why you see these small little through faults come through. And it's not an individual fault that fails the unit, it's the accumulation of all these faults and potentially these faults being held in place for too long that has weakened the clamping pressure to where it was no longer sufficient to hold the windings in place during that event.

It's not an individual fault that fails the unit, it's the accumulation of all the small faults that have been held in place for too long, weakening the clamping pressure to where it was no longer sufficient to hold the windings in place during that event.

AR That is incredible insight. The accumulative effect on something, especially a transformer in everything, especially heat. Transformers are all rated so that you can run it over for a certain period of time. But the longer you do that over a longer period of time, you are having to deal with heat that has another impact on cellulose and everything else. I never heard that about the clamping. I never thought about that. There is a great video by GE showing the transformer that just suddenly comes apart as a catastrophic failure from a lot of different little things.

So, you have given us the problem. What is the solution? Because I find very few people out there who are taking what I would consider to be robust best practices for breaker testing, maintenance, and monitoring.

CR I feel like a lot of that has got lost with the newer breakers, the vacuum breakers, and SF6. There really is less maintenance involved there. With the old OCB type, which I dealt with because 60% of our fleet was still OCB when I left the power company, there was an art to that. And I feel like some of that over the time has kind of gotten away from the utilities in general. Some of that expertise has moved out. You have breakers with low maintenance, so the training that's applied is not as intensive anymore. So, the biggest solution is to be able to track those through faults. And there are several ways that that can be done. We here at DR, we have several products that allow for this. We have our E3 products which actually have fault counting on it. So, you see the amplitude and duration of every fault that's gone through that transformer, and we also offer breaker monitoring. One of the important things about breakers that I really stress, is the importance of gathering a baseline of the waveform capture of the trip coil and face currents.

Those waveforms, the profiles of the coils, should overlay perfectly. There should be no more than two milliseconds of discrepancy. If you are seeing more than that, it means there are some lubrication issues going on, something's going wrong with that breaker and it is only going to become worse over time if it isn't addressed. The problem in many cases is that the breakers are just not operated that often. You need to go to the maintenance site and exercise those breakers every year. The longer a breaker just sits there, the more likely it is to fail.

When it comes to the statistics of breaker failures, around 80% of them are minor. Meaning, the breaker didn't open in time. With major failures, you're getting on up in the 90-percentile range of the failure being directly related to a mechanical portion of that breaker not functioning as it should. And out of those, from my experience, most of the time it will be a lubrication issue. In the breaker, there is grease which has a couple of components - the oil part, which could be mineral oil, or it could be a floor of silicone. That's your lubricant. And then there is a thickener, which is clay or soap that holds that lubricant in place. So, if that breaker sits there, and isn't operated for three or four years, over time, you start to get separation of these two components. That oil will leach out of that thickener, and what you're left with is just a gum-type substance in your breaker. This is why I moved to first trip testing as I was leaving the utility. Once we started doing that, I would see breakers that may take 400 milliseconds to open the first time and on the second operation, it would actually open in 30 milliseconds because by opening and closing it, you mix the grease back up and it's back where it should be. I would definitely recommend that you at least do a first trip every couple of years to get the real-life timing of that record.

In the breaker, there is grease which has a couple of components - the oil part and a thickener. If the breaker isn't operated for three or four years, over time, this will lead to separation of these two components.

Because you don't get a warm-up run on a fault. You don't get to exercise once and then try to clear it. The breaker has got to do its job the first time. And from all my experience, I can tell you that that first trip, can be just unbelievably long. And if you're taking that thing out of service to test it, you're missing a lot of data and don't even

know that you have a problem. Now that we're doing monitoring, we're capturing data in a very similar way to this first trip with the waveform capture. And during the monitoring, we've had a couple of instances where a breaker was three milliseconds slow to open initially, and maybe two weeks later, it was six milliseconds slow, and then a month later it had a 20-millisecond delay. So that's something you really need to keep an eye on. And just exercising the breakers on a regular basis makes a huge difference.

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AR Let's talk about SF6 briefly. I know there is a new gas being developed to replace SF6. Why do SF6-free breakers require so much less? And don't they have the same mechanical issues?

CR They do, but they have fewer moving parts. SF6 is such a good insulator, you really don't have to have a lot of separation of contacts to interrupt that arc. With the old OC breaker, you are looking at about 12 inches of travel that that breaker was having to go through to actually have enough distance in those contacts to make an interruption. With these, it's interrupting in a fairly short throw.

AR Do you still monitor those?

CR Yes, we do. When it comes to monitoring, there are other things to take into consideration as well. There are things that get missed a lot in internal inspections or in routine inspections. For instance, when it comes to cyclic maintenance, you are doing your timing test and you will run a contact-resistance test of the breaker. Or take for example a pneumatic breaker. If you have leaks developing in that system, that motor could start 20 times a day. But I've seen instances, and I can't tell you how many times this has happened, where we were doing testing on a pneumatic breaker and had a motor burn up and we were constantly left with one that won't operate. And that is why we monitor all of these different parts, including motors. At DR, we've actually divided motor starts up into a couple of groups just because of the different types of mechanisms. We have motor starts that are associated with breaker operations. And that would mean that if you have a spring-tight mechanism, you're going to expect a motor run on the close, and you shouldn't see any other motor starts associated with that breaker. If you start seeing extra starts after that, there is something wrong with your stored energy system or controls or something like that.

When you get into pneumatics and hydraulics, pneumatics have a design leak built into the system because you want that compressor to run once a day just to keep condensation out of the lines. So, when you have those separate motor runs that aren't associated with that breaker operating, we count those separately from the runs associated, and we set a limit on that. So, it's an excellent leak detector at that point. Because the average is one-two motor runs a day and if suddenly the average jumps to four or five, you've developed a leak in that system, and you need to get out there and take a look at it. That's something I actually learned after coming here. I had never considered how many times a breaker motor runs during the day when I was in utility because I wasn't sitting next to one 24 hours a day. But now that we have monitoring and we count these excessive starts, we immediately realize that we need to stay close and on top of it to see if it is a leak or if it's just a hydraulic system that has lost pressure because it got colder and it had to have a motor run. So, we track those differently to keep up with leaks in these systems, which extends your motor life on the breaker greatly, meaning that it is one less miss-operation you are going to have.

AR I have one last question for you, Chris, and this is an important one. When you think about monitoring, it creates information, creates data. There's a certain amount of data that you are tracking. A lot of what you are describing, though, is that somebody has to look at that data and make a decision to do something. In terms of the monitoring that Dynamic Ratings is doing, how do I, as an operator, depend upon you? Do you have to say to me, "Hey, look at the data!" or are there alarm systems? What makes it so that we don't fail to act?

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You've got to have a definite action plan in place. The way the breaker monitor is set up, all the data is coming out over the in-house tool that you have. I set interrupting time alarms very tight, so that a very small change is going to send you an alarm.

CR A lot of thought went into that actually, Alan. That was something I really stressed as an asset manager when I was with utility. You've got to have an action plan in place. It can't be, "Oh, we've got an alarm," and they just shut down the alarm because everything looked okay. And that happens more than you care to think it does. Or in the case of transformers, you get a hydrogen alarm, and the reaction is "Well, everything seems fine, just clear it." And nobody even checks to see if everything really is fine. You've got to have a definite action plan in place. The way the breaker monitor is set up, all the data is coming out over a SCADA. So this would be coming into an in-house tool that you have. I set interrupting time alarms very tight, like I said, so that a very small change is going to send you an alarm. Heater goes out, motor problems, any of these alarms, they will all come in over your SCADA system, at which point you will receive an alarm through whatever in-house software you are running. It's at that point that you can dial in to the breaker monitor over Ethernet. You can go in and pull the web page up and it allows for a comparison of the waveforms. And after looking at them, we can see whether it looks like a latch issue, or a main bearing issue, or a wiring issue. And these are all things you can identify readily from the waveform capture. As I mentioned before, you get a baseline when you first do this and then every operation after that, you can always compare to how that breaker was performing. And you are looking for changes. It is very similar to monitoring a transformer. You look for changes and you are checking to see if some component did something different. And then of course, you've got to have an action plan. The great thing about monitoring is that it allows whoever is observing the process to do some pretty good analysis as to whether a latch didn't come loose, or the main bearings took too long to get the contacts open. This in turn allows you to give your crews very specific instructions. When I was working at the utility, I learned that when you can give your maintenance crew specific instructions on where the issue is or what to look out for, you get far better results.

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AR Chris, you are a wealth of knowledge. I am inviting you back again for phase two of this discussion because I really want to talk about that action part.

CR Yes, I would like that.

AR I would also like to make a point that there is a lack of people out in the marketplace who understand what you understand, because we've had a whole generational transfer of people leaving without the next group of people understanding what to do. So, we are going to have to give them a hand and let them know "Hey, when it says this, do this."

CR I agree, it has become almost like the Pass the Message game. You all whisper, and that's how knowledge gets passed down. It gets watered down as it goes, and eventually, it gets lost. No utility that I've ever been to really has a book that says what to do. It's just, well, this is out. And the attitude is often "Well, we've been doing it like this for 50 years." We rode horses at one time too and we upgraded that, so it might be time to upgrade our procedures a little bit too.

AR Chris thank you so much for joining us.

CR Thank you, Alan. It was great to be here.