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Abstract

We recently had an incident where a three phase 480 volt disconnect switch feeding a Booster thyristor control power supply, had a catastrophic failure. The cover of the disconnect switch was found about ten feet away from it, on the floor. This happened while the power supply was on, late at night, and no one was around. This paper describes a way to predict the temperature rise of such a disconnect switch providing one knows the dc operating current and the maximum dc voltage of the power supply, fed by the switch. Further more temperature measurements were made in 480 volt disconnect switches feeding dc thyristor control power supplies. The temperature rise of these disconnect switches was within two to three degrees F, from the predicted results.

1. Description of the event

At about 0415 on May 10th 2007 support group found that Booster Power Supplies QV-3 and QH-4 had no power going to them. On further investigation they found that the QV-3 disconnect switch cover, had been blown over 10 feet away from its box. The switch specifications are the following: 480V, 100A, 600 V.AC, Max HP 75, NP 266209-F, made by GE. Preliminary findings showed the cover was slightly bent, the wires had the insulation burned and exposed copper was covered with green oxidation. The plastic red cover was partially melted. The fuses were removed and some signs of arcing were seen on Phase B. The wires and the torque were examined. On phase A the torque was 98 in.lb (vs. 110 to 120in.lbs prescribed by the manufacturer). On phase B the torque couldn't be determined because the aluminum bolt was galled. On the same phase one strand of wire was loose and the wire was introduced only 60% in the receptacle. (0.45" in the 0.75" length of block), which translates into insufficient contact area. On phase C the torque was 70in.lb. On phase A the insulation was burned 3.40" from the connecting block, on B by 6.50", and on C by 3.50". Examining the bear portion of the wires, one can see that there was a short phase to phase, between A and B, an arc flash occurred and the cover was blown away. See figures 1,2,3,4,5. At the end a new switch of the same type was installed, to continue the operation of the power supplies.

Fig.1

Fig. 2

Fig. 3

Fig. 4

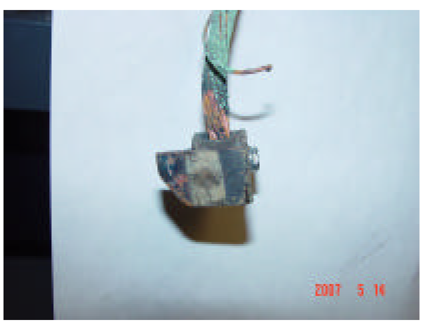

Fig. 5

2. Theoretical thermal analysis of a 480 volts 100 amps disconnect switch

This analysis was performed on a switch with the same specifications as the one described above.

The temperature rise of a fuse disconnect switch, is proportional to the power dissipated on every phase of the switch while it is feeding a power supply. Let us assume that the resistance per phase is R_p. This is the total resistance of the wires connected to the lugs of the disconnect switch, the resistance of the fuse and its connections, and the resistance of the switch itself. Let us also assume that the rms current per phase when the

switch is under load, is Ip. The power Pp dissipated per phase is $Pp \approx Ip^2 \times Rp$ (1). Since we have three fuses the total power dissipated in the switch is, $Ppt \approx 3 \times Ip^2 \times Rp$ (2). Also we know that this power is proportional to the temperature rise of the switch ,Trise. As a result we have $Trise \approx a \times 3 \times Ip^2 \times Rp$ (3). Note a, is the proportionality factor from Ppt to Trise. If we know $a \times Ip \times Rp$ we can predict the temperature rise of the switch with its door closed. Ip can easily be calculated for a thyristor control power supply if one knows the dc current Idc and the maximum dc voltage of the supply Vmaxdc. To prove this we know that $Ip \approx \frac{Vt\sec \times It\sec}{480}$ (4). Vtsec is the transformer secondary voltage, Itsec is the transformer secondary current. Also we know that $It\sec \approx 0.816 \times Idc$ (5) and $Vt\sec \approx \frac{V\max dc}{1.35}$ (6), for a 6 pulse thyristor control rectifier. Substituting equations (5) and (6) into equation (4) we have $Ip \approx 0.00126 \times Idc \times V\max dc$ (7). Substituting equation (7) into equation (3) we have $Trise \approx \frac{a \times Rp \times Idc^2 \times V\max dc^2}{208329.42}$ (8).
Then we decided to use a 480 volt 100 amps disconnect switch as a reference after ensuring it was working properly. The sample switch is feeding the Booster Q2A,2B six pulse thyristor control dc power supply. Idc was equal to 400 amps. The maximum dc voltage Vmaxdc of the power supply was equal to 75 volts. We then measured the temperature rise of the switch Trise, using an infrared heat sensor and it was 5 degrees F. Note the power supply was running at this current for more than two hours to reach thermal equilibrium at the switch. We also tried to find the hottest spot on the switch with its door closed. Plugging these numbers to equation (8) we then solved for the quantity $a \times Rp$ and it was found to be equal to 0.001157. Note that $a \times Rp \approx 0.001157$ is true only for all 480 volt 100 amp disconnect switches the same type as the one used in the Booster power supply Q2A,2B. Equation (8) then becomes
$Trise \approx \frac{Idc^2 \times V\max dc^2}{180060000}$ (9) in degrees F. In a similar manner one can calculate the quantity $a \times Rp$ for other current rating disconnect switches.

3. Measured results

We decided next to measure the temperature rise of 480 volt 100 amp disconnect switches feeding thyristor control dc power supplies. We took measurements on seventeen disconnect switches associated with seventeen supplies located in two different buildings, in building 914 and in building L18. Below is an excel spread sheet with all the data.

BOOSTER 480 V PRIMARY. POWER SUPPLIES. DATE5/17/07

PS CATEGORY	BLDG	PS RATING	PS MANUFACT.	PS DC CURRENT (A)	PS MAX DC VOLTAGE (V)	FUSE DISCONNECT SWITCH CALCULATED AC CURRENT (A)	PREDICTED DELTA T (DEG F)	MEASURED DELTA T (DEG F)
DH1	914	35V@700A	INVERPOWER	320	35	14.1	0.7	1
QV3	914	75V @ 1500A	BNL/PPA	800	75	75.6	20.0	23
QH2A&2B	914	75V @ 1000A	BNL/PPA	400	75	37.8	5.0	5
QV6	914	75V @ 1500A	BNL/PPA	340	75	32.1	3.6	3
QV7	914	75V @ 1500A	BNL/PPA	110	75	10.4	0.4	1
QV1	914	75V @ 1000A	BNL/PPA	440	75	41.6	6.0	6
QV5	914	75V @ 1000A	BNL/PPA	280	75	26.5	2.4	1
QH4	914	75V @ 1000A	BNL/PPA	280	75	26.5	2.4	4
QH8	L18A	30V@500A	INVERPOWER	180	30	6.8	0.2	3
QV9	L18A	35V@700A	INVERPOWER	240	35	10.6	0.4	3
QV11	L18A	40V@300A	INVERPOWER	104	40	5.2	0.1	2
QV13	L18A	75V@1000A	BNL/PPA	220	75	20.8	1.5	2
DH5	L18A	75V@1000A	BNL/PPA	420	120	63.5	14.1	24
QH10	L18A	35V@700A	INVERPOWER	160	35	7.1	0.2	2
QH12	L18A	35V@700A	INVERPOWER	144	35	6.4	0.1	2
DH4	L18A	40V@300A	INVERPOWER	48	40	2.4	0.0	2
QH14	L18A	75V@1000A	INVERPOWER	175	75	16.5	1.0	3

To calculate the fuse disconnect switch current, referenced in the spread sheet, we used formula (7). To calculate the predicted delta T also referenced in the spread sheet we used formula (9). The measured data of delta T are also displayed in the spread sheet. Note that the calculated values of delta T and the measured values, are off by 3 degrees F maximum, except for power supply DH5 in L18A building. This one it seems that the disconnect switch is running 10 hotter than the predicted value. This switch should be investigated further and perhaps replaced.

4. DH5 power supply disconnect switch

As shown in the table above DH5 power supply disconnect switch was running hot compared to the predicted results. On the next maintenance day the switch was replaced with a new one. The measured Delta T in degrees F at 420 Amps dc of the new switch, was 12 degrees F. The old switch was examined and the resistance of the switch contact of each phase was measured. Phase A resistance was 0.28 mOhms, phase B resistance was 4.09 mOhms and phase C resistance was 9.83 mOhms. These numbers indicate that the switch was not functioning properly. The power dissipated on phase C was calculated to be 39 Watts, on phase B 16.23 Watts and on phase A 1.1 Watts. This results in 56 watts total dissipated in the enclosed disconnect switch.

5. Conclusion

Based on the measurements of temperature rise of the above disconnect switches, it seems we should be able to mathematically analyze, and predict the temperature rise of disconnect switches feeding thyristor control power supplies. A similar analysis could be done for disconnect switches feeding different topology of power supplies. Further more, one could develop an automatic way to measure temperature rise of fuse disconnect switches, measure also the dc current of thyristor power supplies and since we know the maximum dc voltage for each supply, we could have a computer algorithm predict if a fuse disconnect is running hot.

6. Acknowledgments

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