A STUDY OF CURRENT-CARRYING CAPACITY OF DRAWLEAD CABLE IN CONDENSER BUSHING

Daxiong Zeng
Senior Member, IEEE
Lapp Insulator Company
LeRoy, NY 14482

ABSTRACT

Temperature rise distribution at the drawlead cables in the condenser bushings was studied with a thermal model and actual thermal tests. Temperature rise of the hottest spot at the cables from the model is consistent with that from the tests within a 10% deviation. Factors that influence working current and overload capacity of the cable were studied. Current-carrying capacities of the drawlead cables with index 105 insulation are presented based on thermal basis of rating.

KEY WORDS: Bushing, current-carrying capacity, drawlead cable, temperature rise, thermal model, thermal test.

INTRODUCTION

High voltage bushings in transformers are either bottom connected or drawlead connected. Because there was no thermal requirement in the IEEE bushing standard for drawlead cable until 1995 [1], there are no general guidelines for current-carrying capacity of a drawlead cable.

Current-carrying capacity of a drawlead cable is determined by temperature rise of the hottest spot. For index 105 insulation, current-carrying capacity of a drawlead cable is the current that makes the temperature rise of the hottest spot equal to 65°C, when the lower end of the bushing is immersed in an oil bath with 55°C temperature rise.

Because the drawlead cable is confined in the bushing stud, its current-carrying capacity is lower than the capacity of the overhead cable. Thermal testing is a method to determine current-carrying capacity of a drawlead cable. Because there are numerous combinations of bushings and cables, performing all the thermal tests would require a great deal of time. Therefore we used a thermal model to obtain guidelines regarding the drawlead cables.

THERMAL MODEL

A bushing in a drawlead application is shown in Fig. 1. The bushing is mounted on a transformer with the top in ambient air and the bottom in hot air and oil. For drawlead bushings there are two oil levels, one is the transformer oil level and other is the cable oil level in the stud of the bushing. Both are measured from the mounting surface of the flange down to the oil surface. These two levels may not be the same.

A daisy-chain circuit model [2,3] is used to study temperature rise distribution at the drawlead cable. In the thermal model, the assumptions are as follows:

1. Radial thermal resistance in metal parts is ignored.
2. Axial thermal conduction in insulation is ignored.
3. Heat transfer from the cable to the stud is thermal conduction in the air or oil gap.
4. Heat transfer from the outer surface of the bushing to the surrounding media is convection.

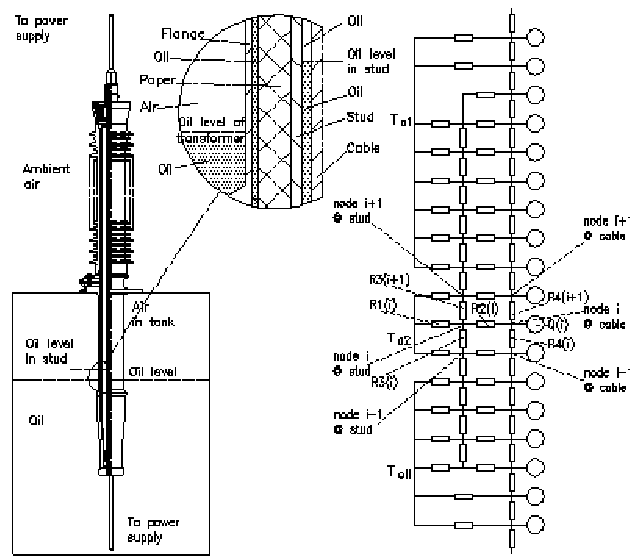

Fig. 1. Drawlead bushing and thermal model

Heat source Q(i) at node "i" depends on current, stud material, geometry dimension and temperature. $R_1(i)$ is radial thermal resistance from the stud to the surrounding media. $R_2(i)$ is radial thermal resistance from cable to stud. $R_3(i)$ and $R_4(i)$ is thermal resistance along stud and cable.

Heat Q(i) at node "i" dissipates through the radial thermal resistance $R_2(i)$ to the adjacent segment of the stud and through the axial thermal resistance $R_4(i)$ and $R_4(i+1)$ to the adjacent nodes "i-1" and "i+1" at the cable. The heat received by node "i" of the stud dissipates through the radial thermal resistance $R_1(i)$ to the surrounding media and through the axial thermal resistance $R_3(i)$ and $R_3(i+1)$ to adjacent nodes "i-1" and "i+1" at the stud.

Thermal resistance $R_2(i)$ varies with the location of the cable in the stud. When the cable is at the center of the stud, $R_2(i)$ reaches the maximum value. We use the maximum value to calculate the temperature rise of drawlead bushings.

Coefficients of thermal conduction and convection of materials are from available sources [4,5]. We consider all thermal coefficients to be constants except the thermal conduction coefficient of the air between the cable and stud. The thermal conduction coefficient of the air gap is corrected based on the local temperature of the cable.

Boundary conditions for calculation are as follows:

1. Portion of the bushing above flange is in the ambient air with uniform temperature T_{a1}.
2. Portion of the bushing between the flange and transformer oil level is in hot air with temperature T_{a2}. T_{a2} may be lower than oil temperature because of the cooling effect of the transformer tank cover.
3. Lower portion of bushing is immersed in the oil bath with uniform temperature T_{oil}.
4. Cables between the bushing and power supply are long enough and there is no heat transfer along the cable at the middle of the connecting cables.

EVALUATION OF THERMAL MODEL

Temperature profiles of a bushing with a draw lead cable are obtained from the thermal model and thermal tests as shown in Fig. 2. The bushing is a 350kV BIL 400A drawlead bushing with 1 1/4" ID aluminum stud. The drawlead cable is a 300 Mcm (ϕ0.629") copper cable. The bushing is immersed to minimum oil level of bushing. The oil level in the stud is maintained at the same oil level as that in oil bath. Because our test data were not obtained at the exact same ambient temperature, in order to compare the thermal model and thermal test, the measured ambient temperature is used in the model to calculate temperature rise profiles of the cable.

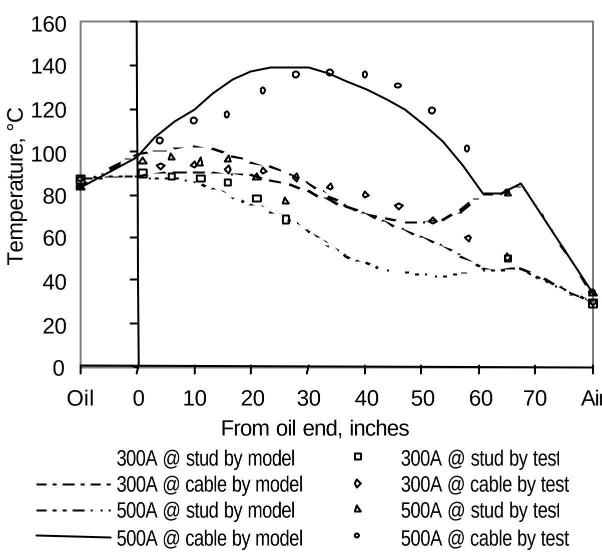

Fig. 2. Temperature rise profiles from the thermal model and the test (a 350kV BIL 400A PRC type drawlead bushing with 300Mcm copper cable)

Temperature rise profiles from the thermal model is consistent with those from thermal tests. The hottest spot is at the cable and it migrates to near the center of the bushing with an increase of current. When the current is high, the temperature of the cable can be much higher than the temperature of the stud. It is noted that the cotton sheath of a 300Mcm cable was carbonized after tested at 600 amps in a 350kV BIL PRC type bushing. This means the temperature of the cable is a limiting factor.

Temperature rises of the hottest spot at the cable in various combinations of bushings, cable size and currents were measured and calculated. Table 1 shows a comparison of measured and calculated temperature rise of the hottest spot. Column 5 shows the tested current I_T. Column 8 is the temperature rises of the hottest spot measured and column 9 is the temperature rises calculated by thermal model with the current I_T from column 5 and ambient temperature from column 6 and 7. Column 10 shows the current I_0, which generates the same temperature rise in the thermal model as in the test.

Table 1. Comparison of the data from thermal test and from the thermal model

Column 1	Column 2	Column 3	Column 4	Column 5	Column 6	Column 7	Column 8	Column 9	Column 10
Bushing Type	BIL, kV	Stud, ID, inches	Cable or Rod Size	Test Current, I_T Amps	Top Air, °C	Oil Rise, °C	H.S. Rise from Test, °C	H.S. Rise from Model, °C	Calculated current, I_0,Amps
PRC	200	1.25	300Mcm	400	29.6	56.2	61.6	64.4	381
PRC	200	1.25	300Mcm	500	32.9	56.6	76.3	84.8	461
PRC	200	1.25	300Mcm	600	32.2	57.3	89.4	113.7	516
PRC	250	1.25	3/0	250	25.2	53.6	62.1	65.3	238
PRC	250	1.25	3/0	300	22.2	61.4	82.0	86.9	286
PRC	250	1.25	3/0	400	23.7	57.8	133.5	136.7	394
PRC	250	1.25	300Mcm	400	22.9	55.0	66.1	68.3	387
PRC	250	1.25	300Mcm	600	22.6	56.4	108.4	127.6	487
PRC	350	1.25	300Mcm	300	29.7	57.6	64.0	61.2	321
PRC	350	1.25	300Mcm	400	32.8	52.5	75.5	76.1	396
PRC	350	1.25	300Mcm	500	34.6	48.4	101.7	104.7	499
PRC	350	1.25	ϕ1" rod	800	31.2	54.2	60.1	59.2	819
PRC	350	1.25	ϕ1" rod	1000	30.3	55.8	71.4	73.4	951
PRC	350	1.25	ϕ1" rod	1200	31.6	54.3	93.0	93.4	1196
PRC	350	1.25	ϕ1" rod	1500	32.8	53.5	137.7	140.4	1485
POC	750	1.62	300Mcm	560	33.5	54.6	189.3	159.9	615
POC	750	1.62	ϕ1.5" rod	1350	31.4	56.1	60.0	65.1	1190
POC	750	1.62	ϕ1.5" rod	1500	28.1	65.9	82.3	79.4	1560

Current deviation of the model is defined as

$$A = (I_0 - I_T)/I_0 * 100.$$

Distribution of the current deviation A of the data in Table 1 is shown in Fig. 3. The majority of the data show that the results from the model are conservative. The current accuracy of the model is about 10%.

INFLUENCE FACTORS

Many factors influence the current-carrying capacity of a drawlead cable, some from operation environment and some from bushing design. A load rate K, which is defined as the ratio of current-carrying capacities at a special factor to that at the test conditions defined in IEEE bushing standard, is used to describe the influence of each individual factor quantitatively.

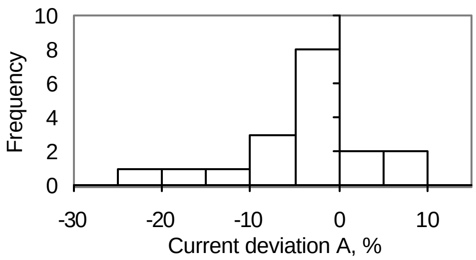

Fig. 3. Distribution of the current deviation of the model

I. TRANSFORMER OIL LEVEL

It is a common opinion that the hottest spot temperature rise of a bushing decreases when the transformer oil level is high because the thermal conduction/convection coefficients of oil are higher than that of air. However, the thermal tests do not support this opinion. The tests show that the hottest spot rise of a bushing increases slightly rather than decreases when the transformer oil level is high.

The hottest spot temperature rise of a drawlead cable at different oil level was calculated. The hottest spot rise of the cable decreases, but not significantly, when the oil level is high if the air space above the oil level is at the same temperature as the oil. For example, at the 450 Mcm cable in a 350kV BIL PRC bushing, the hottest spot rises of the cable at 416A (the rated current) show no significant change with the oil level. The hottest spot rise of the cable at 624A (1.5 rated current) is 98.4°C when the oil level is at flange mounting surface. However, it is 100°C when oil level is 16.5” down from flange mounting surface.

The reasons are:

1. Small portion of the heat dissipates in radial direction at the hottest spot, which is under the flange.
2. The radial thermal resistance from the bushing surface to the surrounding media is only a small portion of the thermal resistance from the cable to the surrounding media.
3. The hottest spot rise of the cable over the surrounding media below the mounting surface of the flange is less than 10°C at rated current.

The thermal tests show that the air space above the oil is always cooler than the oil, even if the oil tank is covered with a thick canvas. Typically the air space above the oil is 10°C to 20°C cooler than the oil. This is because the metal cover of the oil tank works like a radiator and it cools the air above the oil. The cooler air above the oil helps to cool the middle portion of the bushing where the hottest spot of the bushing usually occurs. When the oil level is high, the cooler air space becomes smaller. Therefore, the cooling effect from the air space decreases, and the bushing temperature rise increases slightly. The thermal model proves this explanation. Fig. 4 shows the rise profiles of a drawlead bushing with different air space temperatures.

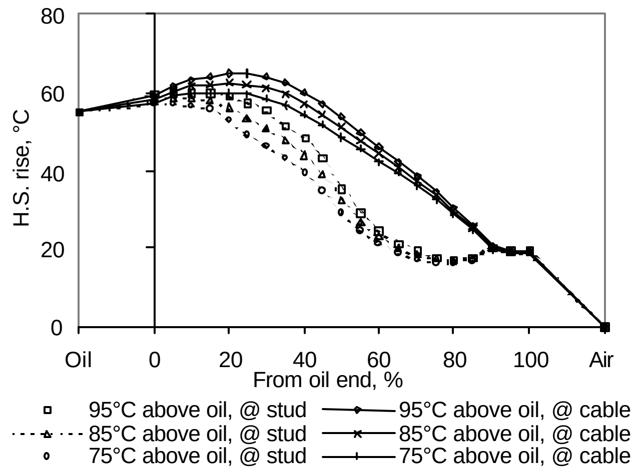

Fig. 4. Temperature rise profiles at different air space temperature (a 450Mcm cable in a 350kV BIL PRC bushing with 416A and 16.5” oil level)

At the same hottest temperature rise, the current-carrying capacity of the cable increases when the transformer oil level is low because of the cooler air space above the oil. The load rate K from the cooler air space above the oil is a linear function of the air space temperature and varies with the cable size and the bushing type as shown in Fig 5.

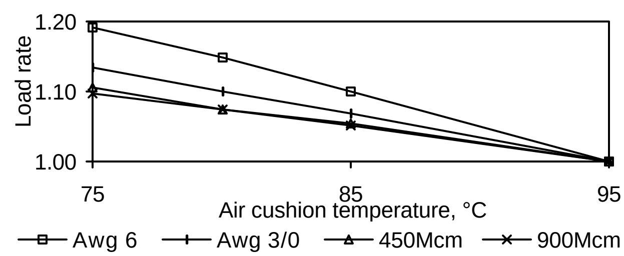

Fig. 5. Load rate due to cooler air space (from 150~350kV BIL PRC bushings)

II. CABLE OIL LEVEL

There are oil and air gaps between the cable and the bushing stud. Because the thermal conduction coefficient of air is worse than that of oil, we can expect that the hottest spot rise at the cable decreases when the cable oil level is pushed higher than the transformer oil level as shown in Fig. 6.

The current-carrying capacity of a cable increases when the oil level in the stud is high. But this is significant only when the cable size is small as shown in Fig. 7.

III. THE AMBIENT AIR TEMPERATURE

A bushing may operate in an environment with ambient air temperature differing from 40°C. For example, if the bushing works in an isolated phase bus duct, the rated current of the cable must be reduced, or the cable may become too hot.

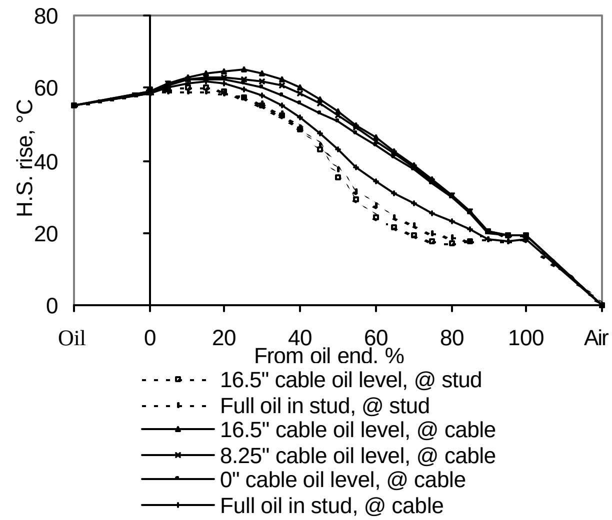

Fig. 6. Temperature rise profiles at different cable oil levels (450Mcm cable in a 350kV BIL PRC bushing with 416A and 16.5" oil level)

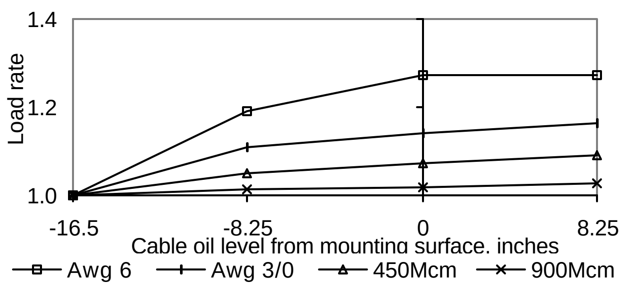

Fig. 7. Load rate due to cable oil level (from a 350kV BIL PRC bushing)

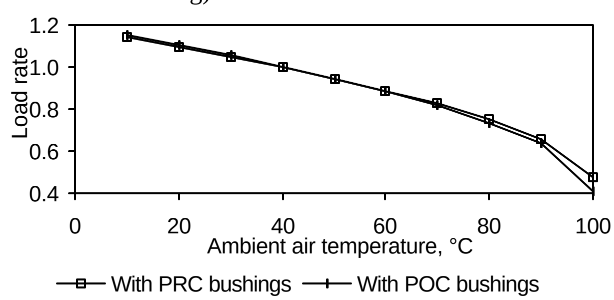

Fig. 8. Load rate due to the ambient air temperature

The load rate due to the ambient air temperature is shown in Fig. 8. The load rate is mainly a function of ambient air temperature and does not change significantly with cable size, bushing BIL or bushing type. This load rate can be used to estimate the current-carrying capacity of a drawlead cable at different air temperatures. For example, if the air end of a bushing is in 90°C ambient air and the oil end in 95°C oil, the working current of its drawlead cable must be de-rated to 65% of the current-carrying capacity at 40°C air.

IV. BUSHING DESIGN

Bushings with a larger minimum oil level have a lower current-carrying capacity as shown in Table 2. If the current-carrying capacity of the cable in a bushing with 16.5" minimum oil level is used as the base, roughly the working current of the same cable in a bushing with 21" minimum oil level should de-rate about 10%.

Bushings with a large stud ID are easier to install a drawing cable but current-carrying capacity of the cable will be reduced. Therefore, a bushing with proper stud ID is recommended.

Copper studs can increase current-carrying capacity of the cable by a few percent depending on the cable size, bushing BIL, oil level and stud ID. The rule of thumb is to use one-step down cable size if the stud is switched from aluminum to copper. For example if 400Mcm cable is used in a bushing with aluminum stud, 350Mcm cable can be used in a similar bushing but with copper stud.

Table 2. Current-carrying capacity of different minimum oil levels

Minimum oil level	10"	16.5"	21"
Bushing	B-89182	B-89181	B-89183
BIL	110 kV	110 kV	110 kV
Stud ID	1.5"	1.5"	1.5"
Cable	Current-carrying capacity of cable		
6 Awg	66	55	50
3/0 Awg	290	241	214
450Mcm	628	540	486
900Mcm	1072	947	865

V. CABLE INSULATION

There is a thin layer of paper tape or cotton sheath to isolate the drawlead cable from the bushing stud. Calculation shows that the thin insulation around the cable, for example 1/16" thick paper insulation, does not have a significant influence on current-carrying capacity of the drawlead cable.

CURRENT-CARRYING CAPACITY OF DRAWLEAD CABLES

The current-carrying capacity of different cables in different bushings is calculated based on thermal basis of rating. The conditions for calculation are as follows:
1. Ambient air temperature is 40°C.
2. Oil levels are at the bushing minimum oil level.
3. Temperature rise of ambient below flange mounting surface is 55°C, including air space above oil.
4. There is no extra insulation around the cable and the cable locates at center of stud.
5. The cable connecting the bushing top terminal to the power supply is the same size as the drawlead cable in the bushing stud.
6. The temperature rise of the hottest spot at the bushing and the drawlead cable is limited to 65°C rise.

Current-carrying capacity of drawlead cables or rods in typical bushings is given in Tables 3 and 4. The current carrying capacity of a drawlead cable varies 15% with the bushing BIL class. That is because the length of the bushing and the thickness of the insulation increase with BIL. The two factors impede the cooling.

When the temperature index of the cable insulation is higher than 105, the current-carrying capacity of the cable should be determined by the temperature rises at the bushing and at the cable, whichever exceeds the limit first. Our calculation shows that current-carrying capacity of drawlead cable can increase about from 17% if the cable has temperature index 115 insulation instead of index 105 insulation, as shown in Appendix.

Table 3. Current-carrying capacity of drawlead cables or rods in 110~350kV BIL paper-resin bushings (based on 65°C drawlead cable rise)

BIL	110kV	150kV	200kV	250kV	350kV
Stud ID	1 ½	1 ¼"	1 ¼"	1 ¼"	1 ¼"
Air	40°C				
Oil Rise	55°C				
Oil Level	16.5"	16.5"	16.5"	16.5"	16.5"
Stud	Aluminum				
Bushing	B89181	B89201	B89301	B89401	B89501
Cable	Current @ 65°C cable temperature rise				
6 Awg	55	54	53	52	51
5 Awg	66	64	63	61	60
4 Awg	79	76	74	72	71
3 Awg	93	89	87	83	82
2 Awg	111	106	103	98	97
1 Awg	135	127	123	117	114
1/0 Awg	163	152	147	139	135
2/0 Awg	196	183	176	166	160
3/0 Awg	241	223	215	201	194
4/0 Awg	293	270	259	242	232
250 Mcm	332	305	293	272	261
300 Mcm	387	356	341	315	301
350 Mcm	440	402	387	357	340
400 Mcm	490	449	432	398	379
450 Mcm	540	496	475	439	416
500 Mcm	588	540	519	477	454
600 Mcm	683	628	606	556	529
700 Mcm	773	713	689	632	603
750 Mcm	811	747	725	664	632
800 Mcm	862	798	771	709	675
900 Mcm	947	879	858	786	751
1000Mcm	1032	N/A	N/A	N/A	N/A
1100Mcm	1111	N/A	N/A	N/A	N/A
1200Mcm	1191	N/A	N/A	N/A	N/A
1.000" rod	956	891	868	800	766
1.125" rod	1143	1078	1059	980	942
1.250" rod	1342	N/A	N/A	N/A	N/A
1.375" rod	1547	N/A	N/A	N/A	N/A

PERMISSIBLE OVERLOAD RATE

According to IEEE guide [1], general temperature limitations for bushings loaded beyond nameplate rating are:

1. Ambient air temperature: 40°C maximum
2. Immersion oil temperature: 110°C maximum
3. Maximum emergency current: Two times rated current of the bushing
4. The temperature rise of hottest spot at the bushing and the cable: The hottest spot of the conductor in contact with temperature index 105 insulation should be limited to 150°C.

When a bushing is under overload condition, the temperature rise of the hottest spot at the cable can be estimated accurately if the temperature profiles of the bushing and the cable with rated current and without current are known [2]. Because the main concern is whether a cable or bushing will be too hot under overload conditions, there is a simple way to estimate overload capacity of drawlead cable. The thermal model shows that the steady temperature of the hottest spot of any cable at two times rated current will be much higher than 150°C if the cable just passes a thermal test at rated current. Calculation shows a drawlead cable can handle an overload of 1.43~1.64 times rated current if the hottest spot temperature is limited to 150°C. Permissible overload rate of drawlead cable changes with cable size and bushing type slightly as shown in Table 5 and 6. For the sake of simplicity, a constant 1.5 can be used as a permissible overload rate for all the drawlead cables.

Table 4. Current-carrying capacity of drawlead cables or rods in 550~900kV BIL paper-oil bushings (based on 65°C drawlead cable rise)

BIL	550 kV	650 kV	750 kV	900 kV
Stud ID	1 5/8"	1 5/8'	1 5/8"	2"
Air	40°C			
Oil Rise	55°C			
Oil Level	23.5"	23.5"	23.5"	26.75"
Stud	Aluminum			
Bushing	POC550/0800	POC650/800	POC750/800	POC900/800
Cable	Current @ 65°C cable temperature rise			
6 Awg	50	50	51	49
5 Awg	58	59	59	57
4 Awg	68	68	69	66
3 Awg	78	78	78	75
2 Awg	91	91	91	88
1 Awg	107	107	107	102
1/0 Awg	125	125	125	119
2/0 Awg	148	147	147	139
3/0 Awg	177	176	175	165
4/0 Awg	210	207	205	194
250 Mcm	233	231	229	215
300 Mcm	268	264	261	245
350 Mcm	300	296	291	273
400 Mcm	334	327	322	300
450 Mcm	364	358	352	327
500 Mcm	396	388	380	353
600 Mcm	459	448	438	405
700 Mcm	519	506	494	454
750 Mcm	544	530	517	476
800 Mcm	579	563	550	503
900 Mcm	640	620	604	550
1000 Mcm	701	678	657	598
1100 Mcm	759	734	710	646
1200 Mcm	822	791	765	692
1300 Mcm	881	848	818	738
1.000" rod	657	638	621	569
1.125" rod	802	773	750	684
1.250" rod	960	923	891	809
1.375" rod	1137	1090	1049	943
1.500" rod	1334	1276	1225	1092
1.625" rod	N/A	N/A	N/A	1252
1.750" rod	N/A	N/A	N/A	1424

The cable size in a drawlead bushing should be determined by combining normal operating conditions with emergency operating condition. If emergency current is less than 1.5 times rated current, cable size can be selected based on rated current; otherwise based on emergency current.

CONCLUSION

The study shows the temperature rises of the drawlead bushing can be calculated from a thermal model within a 10% deviation. This paper presents the method of calculating current carrying capacity of a drawlead cable and guidelines to choose the size of the drawlead cable. In general a drawlead cable can handle an emergency overload of 1.5 times rated current.

Table 5. Allowable overload rate of drawlead cables in 110~350kV BIL paper-resin bushing

BIL	110kV	150kV	200kV	250kV	350kV
Stud ID	1 ½	1 ¼"	1 ¼"	1 ¼"	1 ¼"
Air	40°C				
Oil Rise	55°C				
Oil Level	16.5"	16.5"	16.5"	16.5"	16.5"
Stud	Aluminum				
Bushing	B89181	B89201	B89301	B89401	B89501
Cable	Allowable overload rate @ 150°C cable temperature				
6 Awg	160%	163%	164%	164%	164%
1/0 Awg	151%	155%	156%	157%	158%
250 Mcm	148%	152%	153%	154%	155%
500 Mcm	145%	149%	150%	151%	153%
900 Mcm	143%	149%	150%	151%	153%

Table 6. Allowable overload rate of drawlead cables or rods in 550~900kV BIL paper-oil bushing

BIL	550 kV	650 kV	750 kV	900 kV
Stud ID	1 5/8"	1 5/8'	1 5/8"	2"
Air	40°C			
Oil Rise	55°C			
Oil Level	23.5"	23.5"	23.5"	26.75"
Stud	Aluminum			
Bushing	POC550/0800	POC650/800	POC750/800	POC900/800
Cable	Allowable overload rate @ 150°C cable temperature			
6 Awg	153%	153%	152%	152%
1/0 Awg	150%	149%	150%	149%
250 Mcm	149%	148%	148%	148%
500 Mcm	147%	147%	147%	147%
1100 Mcm	147%	147%	147%	147%

REFERENCE

[1] IEEE Guide for Application of Power Apparatus Bushings, IEEE Std C57.19.100-1995

[2] D. Zeng, An Improved Method for Estimating Temperature Rise of a Bushing Loaded above Nameplate Rating, IEEE Trans. on Power Delivery, Vol. 14, No. 2. 1999

[3] W. J. McNutt and J. K. Easley, Sr, "Mathematical Modeling - a Basis for Bushing Loading Guides", IEEE Trans. on Power Apparatus and Systems, Vol. PAS-97, No. 6, Nov/Dec 1978

[4] R. Bean and etc, Transformers for Electric Power Industry, McGraw-Hill, 1959

[5] Y. Bayazitoglu and etc, Elements of Heat Transfer, McGraw-Hill, 1988.

BIOGRAPHY

Daxiong Zeng received his BS and MS degrees in high voltage engineering and electrical measurements from Tsinghua University, Beijing, China.

During 1968~1985 he worked at Xi-an Power Rectifier Company in China to develop AC-DC and DC-AC energy conversion systems and at the Electrical Engineering Institute of Chinese Academy of Sciences to develop high-voltage impulse generators and work on high-voltage insulation projects.

In the US, he worked as a visiting scientist at the Plasma Lab of Stevens Institute of Technology. Since 1990, he has been with Bushing Division of Lapp Insulator Company and now he is a chief engineer. His responsibilities include bushing design and bushing development.

(E-mail address: dzeng@lappinsulator.com)

APPENDIX

Following Table shows the current-carrying capacity of drawlead cables in 550~900kV BIL paper-oil bushing when the drawlead cable rise is to 75°C and the bushing stud rise is limited to 65°C. Comparing the data in this table with those in the table 4, We can draw the conclusion that current-carrying capacity of drawlead cable can increase about 17% if the cable has temperature index 115 insulation instead of index 105 insulation.

BIL	550 kV	650 kV	750 kV	900 kV
Stud ID	1 5/8"	1 5/8'	1 5/8"	2"
Air	40°C			
Oil Rise	55°C			
Oil Level	23.5"	23.5"	23.5"	26.75"
Stud	Aluminum			
Bushing	POC550/0800	POC650/800	POC750/800	POC900/800
Cable	Current @ 75°C cable temperature rise			
6 Awg	60	60	60	58
5 Awg	69	70	70	67
4 Awg	81	81	81	78
3 Awg	93	93	93	89
2 Awg	108	108	108	103
1 Awg	127	126	126	120
1/0 Awg	148	148	147	140
2/0 Awg	174	173	172	163
3/0 Awg	209	207	205	194
4/0 Awg	247	244	241	227
250 Mcm	274	271	268	252
300 Mcm	315	310	306	287
350 Mcm	353	347	343	320
400 Mcm	391	384	377	352
450 Mcm	428	419	412	383
500 Mcm	465	454	445	413
600 Mcm	537	525	514	474
700 Mcm	609	593	579	532
750 Mcm	639	621	605	556
800 Mcm	679	660	642	589
900 Mcm	751	727	708	645
1000 Mcm	821	794	771	701
1100 Mcm	890	861	835	757
1200 Mcm	962	927	899	811
1300 Mcm	1034	994	961	865