# Loss Calculation and Fluid-Thermal Field Coupled Analysis of Bridge Arm Reactor

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**Abstract**

Bridge arm reactors are subjected to composite current of AC and DC in operation, having both AC current distribution characteristics based on inductance distribution and DC current distribution characteristics based on resistance distribution. Aiming to study the differences in temperature rise, current and loss calculations are performed according to electromagnetism and heat transfer theories. The static temperature distribution law of the reactor and its influencing factors are analyzed. The results show that the loss of metal accessories accounts for 1.02% and the collector ring is prone to local overheating. The maximum temperature rise of the encapsulation shows a nonlinear decrease with the increase of the flow rate and the decrease of the ambient temperature. The winding hottest spot temperature in AC condition is higher than that in DC condition. The temperature distribution is more uniform in DC condition. Compared with the AC and DC temperature rise test results, the maximum error of each encapsulation is 6.08% and 2.49% respectively, which verifies the correctness of the simulation model. The research results can provide reference for the design of temperature rise of reactors under AC-DC compound high current in actual engineering.

## 1 Introduction

Bridge arm reactors are subjected to high AC-DC compound currents of comparable current amplitude in normal operation, which will result in different distribution of losses and temperature rise in the encapsulations [1-2]. The previous studies mainly focused on the temperature field characteristics of dry air-core reactors under the action of a single AC or DC current. There is less research on simulation and numerical calculation of bridge arm reactors, and the part that has been carried out takes less account of the influence of the main structural components and sound insulation devices. The temperature characteristics of bridge arm reactors under actual working conditions have not been comprehensively analyzed. Therefore, it is important to analyze and study the temperature field of the bridge arm reactor package and structural fittings and their influencing factors [3].

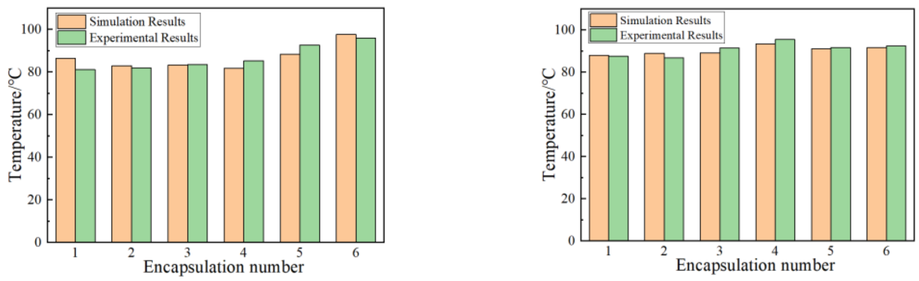
## 2 Loss Calculation and Temperature Field Distribution of Bridge Arm Reactor

$$\begin{cases} \omega(n_1 n_1 f_1 I_1 + n_1 n_2 g_{12} I_2 + \cdots + n_1 n_n g_{1n} I_n) = U_{\mathrm{N}} \\ \omega(n_1 n_2 g_{21} I_1 + n_2 n_2 f_2 I_2 + \cdots + n_2 n_n g_{2n} I_n) = U_{\mathrm{N}} \\ \vdots \\ \omega(n_1 n_n g_{n1} I_1 + n_2 n_n g_{n2} I_2 + \cdots + n_n n_n f_n I_n) = U_{\mathrm{N}} \\ I_1 + I_2 + \cdots I_n = I_{\mathrm{N}} \end{cases} \tag{1}$$

where, $n$ is the total encapsulations number of the bridge arm reactor; $I_i$ 、 $I_j$ are current vectors in each layer; $I_N$ is rated current; $U_N$ is rated voltage; $\omega$ is angular frequency; $n_i$ 、 $n_j$ are the number of turns of the windings; $f_i$ 、 $g_{ij}$ are the geometric coefficients of self-inductance and mutual inductance.

Table 1 Heat Source Density of Each Layer Under AC/DC/AC-DC Working Condition (75℃)

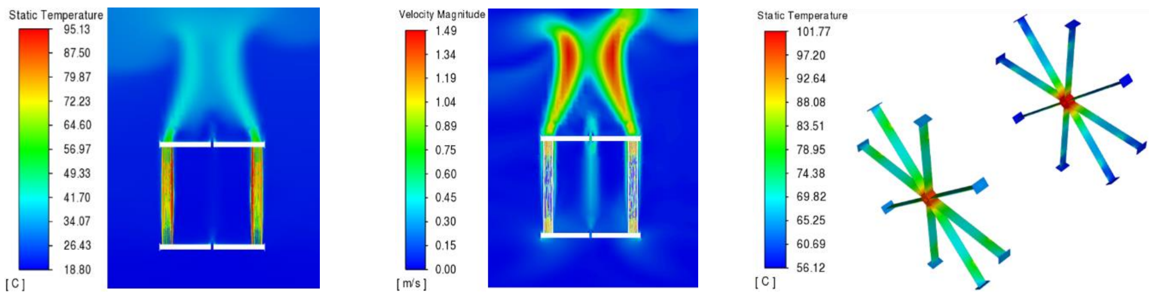
| Encapsulation Number | AC(1233A) Working Condition/(W/m$^3$) | DC(1367.1A) Working Condition/(W/m$^3$) | AC(1091A)-DC(635A) Working Condition/(W/m$^3$) |
|---|---|---|---|
| 1 | 25338.41627 | 22312.46679 | 24646.281 |
| 2 | 20510.97652 | 23047.88004 | 21028.6748 |
| 3 | 26739.31142 | 23513.68181 | 26005.6988 |
| 4 | 22806.41237 | 23542.60021 | 22932.9121 |
| 5 | 25161.75829 | 23154.54573 | 24693.1479 |
| 6 | 21678.03026 | 22150.19421 | 21746.5131 |




(a) Simulation and experimental results (AC condition) (b) Simulation and experimental results (DC condition)

Figure 1: Results of temperature fields under AC and DC condition

The hottest spot temperature of encapsulations is 98.68 and 94.1 ℃ under AC and DC conditions, respectively. From the innermost layer to the outer encapsulation, the temperature of the measurement point decreases gradually under AC condition, which is consistent with the experimental results. The temperature distribution is more uniform under DC condition based on resistance distribution characteristics. The temperature difference between encapsulations is 19.4 ℃ under AC condition, which is larger than under DC condition. The temperature distribution law under AC-DC compound working condition has both AC and DC characteristics.




(a) Temperature distributions of reactor (b) Distributions of fluid velocity (c) Temperature distributions of spiders

Figure 2: Results of temperature fields under AC-DC condition

## 3 Conclusion

The difference of DC and AC distribution characteristics leads to the complete difference of loss and temperature rise distribution in the encapsulations. The loss of spiders has little effect on the temperature distribution of the encapsulations. But all the current is imported into the collector ring, and the highest temperature rise reaches 101.77 ℃, which tends to form local hot spots.

## References

[1] Zhu Junlin, Zhao Linjie, Li Ruihai. "Study on Temperature Rise Test of Valve Bridge Arm Reactor for VSC-HVDC System Based on Equivalent Loss," 2020 15th IEEE Conference on Industrial Electronics and Applications (ICIEA). IEEE, 2020, pp.625-629.

[2] Q. Hou, et al, "A combined-constraints-based optimization methodology aimed at temperature balancing for radial layered encapsulation structure of bridge arm reactor," IET Generation, Transmission & Distribution, 2022, 16, (20), pp 4176-4186.

[3] IEC 60076, Power transformers - Part 6: Reactors, 2007.