The Stability Analyses of the Overheat Controller Unit

Zhao Wenzhi and Liu Weiqiang

Abstract: A false signal problem of the bleed air leak detection system in a widely used modern airplane is studied in this paper. It is considered to be a problem of stability of the controller unit. An equivalent circuit is extracted from the study. The circuit is considered to be an alternative bridge. A mathematical model is derived to describe the stability of the circuit. The conclusion is drawn that the sending of the false signal is relevant to not only the sensors, but also the detector. If a parameter in the detector is readjusted, then the problem may be avoided.

Keywords: Air bleed system, false signal, circuit stability, leak detection.

1. INTRODUCTION

The problem of false signal in the bleed air detection system in a plane of a modern type is important and difficult. It is not solved, though the planes fly everywhere. The false signal usually comes up in the hot whether. The troubleshooting is a difficult maintenance work. The function of the leak detection was occasionally cut off on ground, and turned on in the air when the false signal appeared. It is a challenge to the maintenance engineer.

The judgment of the false signal is easy. And if the false signal were appearing all the time, it is easy to find it according to the trouble-shooting manual, even though it is a tedious work. The method to look for the questioned sensor is a kind of binary way according to the trouble-shooting manual. The signal no matter true or false, is due to the thermal resistive sensor. The sensor is a thin and long cylinder metal line, with the Inconel conductor as the shell tube, and nickel as a center conductor. It is filled with porous aluminum oxide ceramic between the shell and the center. The air spaces between tubing, ceramic and wire and porousing of the ceramic are saturated with eutectic salt mixture. If a few inches long sensor is heated by the air from the leaked bleed pipes, the resistance of the sensor will decrease sharply. The sensor lines are installed in serial along the bleed pipe in the wings. Thus the air bleed pipes are permanently monitored for leaking.

The shell is linked to the fuselage of plane at the connections having the potential of ground. The center of the sensor is linked to the alternative signal source in the detector. The length of one piece of the sensor is from more than one meter to more than four meters. The connected sensors installed in the wings are more than several decades long in meters. If there is a report of signal appeared, and disappearing at hand, it will be a baking time. The engineers can not find which sensor piece sent the false signal. It would frustrate the engineers, because of happening every now and then. All the sensors have to be replaced at the first maintenance of this plane type. But not so many spare sensors are available. The air company could not prepare all of them required. The last way can only be waiting, until its coming up again, not disappearing. The false signal problem challenges not only the maintenance engineers, but also the pilots. The crew has to do additional operation to the air bleed system. The air company can only accept the facts.

This study may free the air company from such an embarrassing question in a degree of getting higher stability from the detector circuit in a systemic way.

2. THE MODEL OF THE LEAK DETECTION SYETEM

This study will include the circuit model and its stability model in the view of integrity.

2.1. The circuit of the system

The bleed air detection system is composed of the detectors and the sensors, as showed in Fig. 1, also called overheat controller. The transformer, as showed in Fig.1, accepts 115V/400Hz, and outputs lower voltage to the sensors. The sensors are thermal resistance with negative coefficient. The sensors are connected to the detector by cables. The detectors are circuit devices, described as Fig. 1. It is an equivalent circuit extracted from the complicated actual circuit by deep study. In Fig.1, R_t represents the sensors, by equivalent conversion in this study, and other components in this figure are actual ones.

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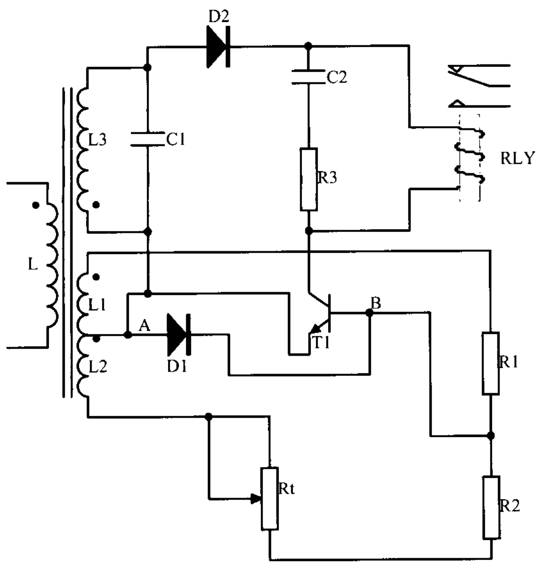

Fig. 1. The schematic diagram of the bleed air detection system.

Because there is not an introduction available to the circuit as showed in Fig.1, an original study has to be carried out. This circuit exhibits the structure of a bridge. It is a transformer bridge. When R_t in Fig.1 becomes lower, the voltage U_B at the circuit point B becomes higher, if enough, the voltage U_{BA} will turn on the transistor T_1, then a relay RLY will be tripped to send leak signal, no matter true or false. A series of operation will be caused automatically.

A true leak signal is caused by actual leak of hot air from the bleed pipe. If a few inches long of the sensor is heated to 120℃, when leaking, the resistance of the thermal sensor decreases rapidly, and the voltage U_B increases consequently. Then a leak signal is sending out. The bleed valves will be shut off to protect the components in the wing not being overheated.

However, the defective sensor may produce the same effect, this is the case of the false signal in hot weather. Generally the resistance of a defective sensor will decrease. Therefore, the result is the same, yet under the preset temperature.

If a sensor becomes weaker in parameters, it will cause false signal in hot weather such as 40℃, but becomes normal in the blow of cool air. That is why the additional operation is needed to do by the crews: the leak detection is cut off on the ground, and turned on in the air. The pilots wish the maintenance engineers would solve the problem completely, but the maintenance engineer could not catch it. Because it appears on chances, not all the time. The ordinary maintenance technique cannot deal with this problem, and it becomes a real difficult problem.

2.2. The stability analyses of the detector circuit

It is considered that the sending of signal be determined by the voltage U_{BA}. The following relationships may be got from Fig. 1:

$$U_{BA} = U_B - U_A \tag{1}$$

$$U_B = \frac{R_1}{R_1 + R_2 + R_t} U_2 \tag{2}$$

$$U_A = \frac{t_1}{t_1 + t_2} U_2 . \tag{3}$$

At the formula (1), U_A is the central voltage of the transformer, as shown in Fig. 1. At the formula (2), U_2 is the voltage output of the transformer. At the formula (3), t_1 and t_2 are the turns of the transformer windings L_1 and L_2. Then U_{BA} may be rewritten as:

$$U_{BA} = \frac{R_1}{R_1 + R_2 + R_t} U_2 - \frac{t_1}{t_1 + t_2} U_2 \tag{4}$$

$$U_{BA} = \frac{R_1}{R_1 + R_2'} U_2 - \frac{t_1}{t_1 + t_2} U_2 \tag{5}$$

where $R_2' = R_2 + R_t$, R_2 and R_t have the same effect to the value U_{BA}, as they are connected in serial. And the differential of the formula (5) will be:

$$\frac{dU_{BA}}{dR_2'} = -\frac{R_1}{(R_1 + R_2')^2} U_2 \tag{6}$$

then the increment of U_{BA} may be written as:

$$\Delta U_{BA} = \frac{dU_{BA}}{dR_2'} \Delta R_2' \tag{7}$$

$$\Delta U_{BA} = -\frac{R_1}{(R_1 + R_2')^2} U_2 \, \Delta R_2' \tag{8}$$

$$\Delta U_{BA} = -k \, \Delta R_2' \tag{9}$$

$$\Delta R_2' = \Delta R_2 + \Delta R_t \tag{10}$$

$$k = \frac{R_1}{(R_1 + R_2')^2} U_2 \tag{11}$$

where k will be a constant (C), if R_2' keeps unchanged.

If $k = C$, $\Delta R_2' = 0$; then $\Delta U_{BA} = 0$. The preset temperature does not change, however the stabilitylevel of the circuit at lower temperature is enhanced

Table 1. The stability relationship between R_2 and R_t.

($R_1 = 10$ kΩ)

R_2 (kΩ)	R_t (kΩ)
1	> 6.5
2	> 5.5
5	> 1.8
7	> 0.48

Table 2. The resistance of sensor (1#) to temperature.

T(℃)	20	30	50	70	83	92	123	140
R(kΩ)	25	24	23	22	20	15	10	8

Table 3. The resistance of sensor (2#) to temperature.

T(℃)	20	30	40	50	60	70	80	90
R(kΩ)	11.2	11	9.6	9	8.4	8	7.5	7

Discussion:

1. From the formula (9), when $\Delta R_2' \succ 0$ increases, $\Delta U_{BA} \prec 0$ decreases. The more $\Delta R_2'$ increasing, the lower will the voltage U_B be, and the transistor T_1 in the detector will be more difficult to conduct. Therefore, the stability of the detector will be higher at such case.

2. From the formula (10), R_2 and R_t have the same contribution to the stability of the detector circuit. If the stability of the circuit keeps unchanged ($\Delta U_{BA} = 0$), let:

$$\Delta R_2' = 0 ,$$

then
$$\Delta R_2 = -\Delta R_t \qquad (12)$$

That is the increasing in R_2 may counteract the decreasing in R_t. Therefore to prevent the detector from sending signal too early that caused by R_t in hot weather, the R2 may be readjusted increasing.

The circuit in Fig. 1 has been reconstructed to simulate the actual detection controller unit. The simulation to the circuit results in the above analyses.

The simulation result is listed in Table 1 briefly. The simulation is to test the stability of the detection circuit. When $R_2 = 1$ kΩ,if $R_t <= 6.5$ kΩ, then the signal will be emitted. This case is related to the lower temperature (normal temperature). And when $R_2 = 7$ kΩ, if $R_t <= 0.48$kΩ,then the signal will be emitted, corresponding to the case of higher temperature than the normal temperature. The conclusion will be drawn that if the R_2 becomes larger, the stability of the circuit will be enhanced in the normal temperature (lower temperature).

It may be interpreted in another way. If R2 is re-adjusted larger, the circuit will keep stable even the temperature disturbances reduce the value of the sensor resistance R_t.

Some basic data of the sensor resistance are obtained from experiment in laboratory. They are listed in Table 2,3, and 4. The length of the sensor: sensor 1#, 246.6cm; sensor 2#, 165.3cm.

3. CONCLUSION

The problem of false signal has been analyzed in a systemic way, and the conclusion may get that the readjustment of the detector circuit may avoid the occurring of the false signal problem.

The readjustment may bring us the following advantages: Higher stability of the detection system in hot weather; Lower consuming of human resources, working hours and the sensors; Reduction of the additional operation of the crew.

The stability of the circuit is improved by the method proposed in this paper with the same sensors.

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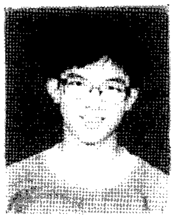

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