DEVELOPMENT OF THE DISPLAY DEVICE OF POWER DISTRIBUTION SYSTEM (DEVELOPMENT OF THE DEPTH FUSED 3-D DISPLAY FOR AIRCRAFT)

Masatoshi Arimoto*, Takafumi Kawadu and Yukio Kamiyoshihara**
***ShinMaywa Industries, Ltd., Kobe, Japan,**
****Japan Aircraft Development Corporation, Tokyo, Japan**

Abstract

The trend of the age of the CO_2 reduction rises, and it aims at risk and the energy saving including B787 in the aircraft industry in recent years. As the technique of energy-saving realization, mitigation of body weight, improvement in engine efficiency, etc. are mentioned. In research of the airplane high efficient systems development which JADC (Japan Aircraft Development Corporation) performs under the Ministry of Economy, Trade and Industry of Japan, our company participated in the development of the power supply control system with Kawasaki Heavy Industries, Ltd., SHINKO ELECTRIC CO., LTD, and Furuno Electric Co., Ltd. for three years. The aim of this development is to produce the distributed Power Distribution System using UMC (Utility Management Center). The new system consists of UMC which contain SSPC (Solid State Power Controllers) and Display Device. UMC are located near the loads and SSPC can be remotely monitored and controlled by Display Device at the cockpit.
Our company took charge of the operation display system (called UMC Control Display) which is the man-machine interface of a power supply system. (Refer to Fig. 1) This paper describes development of a UMC Control Display.

1 Purpose of Development

The charge of the companies in this technology development as follows.

- Examination of the Power Distribution System (Kawasaki Heavy Industries, Ltd.)
- System examination, trial production, and evaluation of UMC (*SHINKO ELECTRIC CO., LTD,*)
- System examination, trial production, and evaluation of UMC Control Display (ShinMaywa Industries, Ltd.,)

The purpose of the technical development of UMC Control Display which our company takes charge of is to realize a high reliability by simplification of the situation monitor by the pilot.
The display for indication (DFD (Depth-Fused 3-D) system (NTT Corporation patent)[1]) which substitutes the operating state of the decentralized power distribution system using SSPC for the conventional circuit breaker panel is used. By displaying on a pilot, We thought that there were merits, such as early detection of a circuit breaker which carried out the trip, and formation of grasp easy of a failed state.
Moreover, not only in flight but in the time of maintenance, We thought that there were merits, such as work load reduction of maintenance by easy-izing of troubleshooting and remote control. A DFD system is a 3D display type by the lamination liquid crystal developed by NTT Corporation.[1] As joint research with NTT Corporation, we developed DFD which can be carried in an airplane with Furuno Electric Co., Ltd. which is a navigation display maker.
As step-up of three years for the last purpose, We carried out the following examination and trial production.

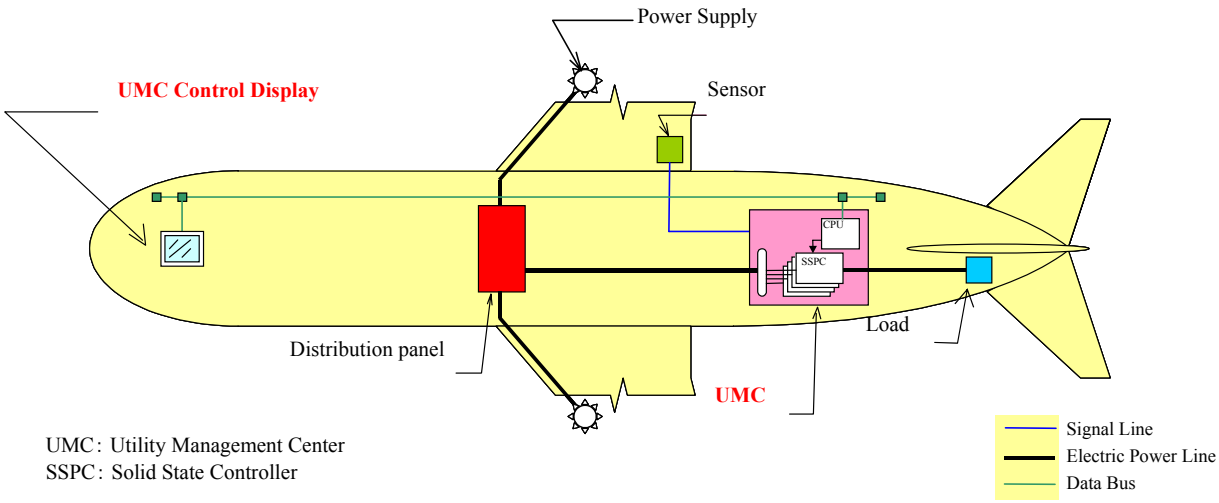


Fig.1 Decentralized supply of electric power making power supply control system

2004:
Basic system examination and part component test (DFD)

2005:
Detailed symbol specification examination and DFD component test

2006:
Detailed system examination and systems evaluation test

2 System Examination

In order to substitute for the conventional circuit breaker panel, it is necessary for this device to display the ON / OFF state of each circuit breaker (this system, SSPC) and a state in each sub system. In addition, it is necessary to reset it at the time of the trip.
Although the conventional circuit breaker panel had a vast area, it is a display for indication of the area restricted with this equipment. Therefore, in order to display these information on a display, hardware and software (including display contents etc.) need to be developed.
So, We adopted the DFD device that improved recognition characteristics by addition of the depth information more to hardware.

2.1 DFD Display

2.1.1 Principle and Structure

About DFD, the principle is explained briefly.(Fig. 2)
It consists of two transparent emitting images. The two images are identical, except that their luminance is different. The image position perceived by the observer depends on the luminance ratio of the two images due to the illusion of the DFD. Recognized depths were almost in proportion to the share of the luminance.

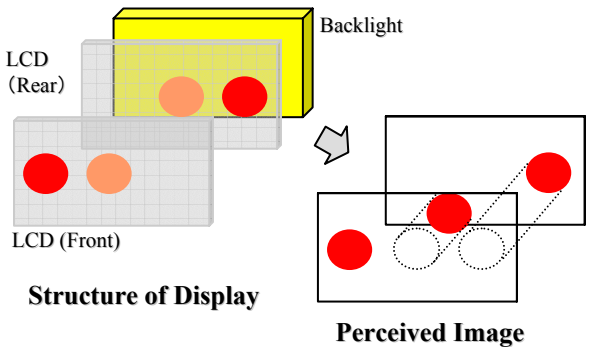


Fig.2 Principle and Structure of the DFD

2.1.2 Luminance

Since DFD is a system which laminates LCDs (Liquid Crystal Display), Even if it uses the LCD panel of high transparency, the transparency of two accumulated LCD is about 1%. (The transparency of one typical LCD panel is about 5 to 10%)

In order to satisfy the demanded display luminance in the cockpit environment of an airplane, a powerful back light will be required.

We thought that the demand could not fully be satisfied with the conventional fluorescent tube back light, and adopted high-intensity white LED. Using 660 LEDs -- we satisfied the specification. demand luminance 257cd/m^2[2] under dark ambient, and achieved 300cd/m^2.

2.1.3 Contrast Ratio and Viewing Angle

Concerning contrast ratio, we satisfied over 20[2] that were specifications demand value and achieved over 300.
Next, there is no specification demand for the viewing angle.
In a side-by-side cockpit, a viewing angle required for a cross-check is considered to be about 50 degrees. The viewing angle of our test product is over 80 degrees direction for upper, lower, right and left.(at contrast ratio over 3)

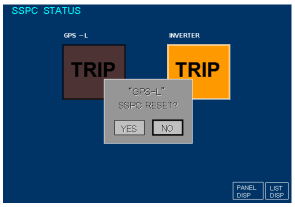
2.1.4 Moiré

With DFD system, moiré occurs inevitably.
Moiré is a striped pattern visually generated by gap of those cycles, when a regular pattern is overlapped.
The general technique which eases moiré is to insert the light diffusion filter in front of the LCD. However, the resolution of the rear LCD resolution decreases. The relation between the grade of moiré and the resolution of rear LCD is a trade-off.
In the test-product which is produced in 2005, the filter whose degree of diffusion is light as much as possible was used, but the visibility evaluation test by pilots was indication that the merit of the 3D display is spoiled with consequence of low rear LCD resolution

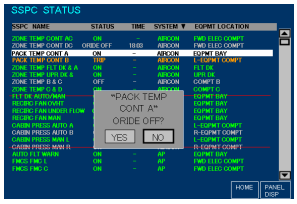
2.1.5 Mode of Display

The results of an investigation in 2004 showed that the demands to the contents of a display differed for pilots and for ground maintenance crews.
Since convenience worsens to becoming of the contents for pilots and the contents for ground maintenance crews a quite different system, we decided measures we assumed the contents being common and to limit functions for pilots.

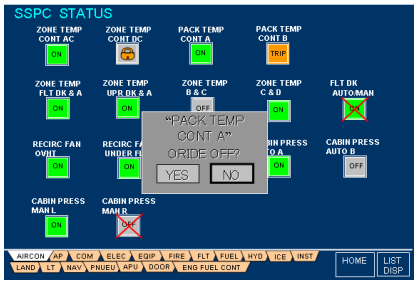
First, for pilots, it was considered as the contents where nothing is displayed at normal operation, and it displays only abnormal SSPC at abnormal operation, unifying into the idea of 'Dark and Silence' in crew alerting system in recent years. It calls "HOME screen" as a default.
In order to display a lot of information on the conventional circuit breaker panel of area which has arranged about 600 circuit breakers on the screen of a limited area, it is disadvantageous at the point that it can recognize at a glance.
In order to overcome this, the "LIST screen" form which abolished the concept of circuit breaker arrangement was adopted.
In addition, the "PANEL screen" form which takes in pilot's opinion that "more acceptable pilots will increase if they used the contents of the circuit breaker placement image together" was adopted.
The "HOME screen" uses the same symbol as "PANEL screen" valuing the reset operability in flight.
These three screens make a change possible by switch operation.
The example of a display of these screens is shown in Fig. 3.



HOME screen



LIST screen



PANEL screen

Fig.3 Example of the contents

2.1.6 Symbol

Concerning the color of the display symbol, it enacted based on the specification of [3], and the symbol definition as shown in Table 1 was performed to each state of SSPC.

Table 1 Symbol definition for the state of SSPC

No	State	Symbols	
1	SSPC ON		Depressed display
2	NO POWER SUPPLY TO LOAD (SSPC OFF)		Depressed display
3	SSPC TRIP		Moves succeeding the depth direction.
4	SSPC OVERRIDE OFF [see Note]		Pop upped and locked Display. (maintenance only)
5	SSPC ON (Current Monitor)		Depressed display. It flashes on and off. (maintenance only)
6	SSPC INVALID (NO-GO)		Last good condition and “X” display.
7	UMC BIT NO GO SSPC		Last good condition and “X” display.

Note: The condition of “OVERRIDE OFF” is equal to conventional circuit breaker pulled up

2.1.7 Measures to moiré reduction and the improvement in rear LCD resolution

Four items are mentioned as a measure for the problem described above, the result which trial and error is done is shown in Table 2 concerning the merit and the demerit for respectively.

In conclusion, we eliminated the diffusion filter for the improvement in rear LCD resolution, and after performing image sharpness processing by software.

Although moiré was conspicuous by doing so, the technique of dark-color-izing of a background color was taken.

The comparison photographs of the existence of a diffusion filter are shown in Fig. 4 and Fig. 5.

Table 2 Measures to moiré reduction and the improvement in rear LCD resolution

Measures	Merit	Demerit
Attaching touch panel	Light diffusion effect in touch panel	Transparency decreases slightly.
Addition of resolution improvement processing by software image processing -NTT Patent-	Resolution improvement (However, with the complicated picture like texture or the photograph it is the effect tremendous, but with the simple graphics like this indication the effect is small)	None
Eliminating the diffusion filter	Resolution improves remarkably	moiré was conspicuous
dark-color-izing of a background color	Moiré stops being conspicuous.	None

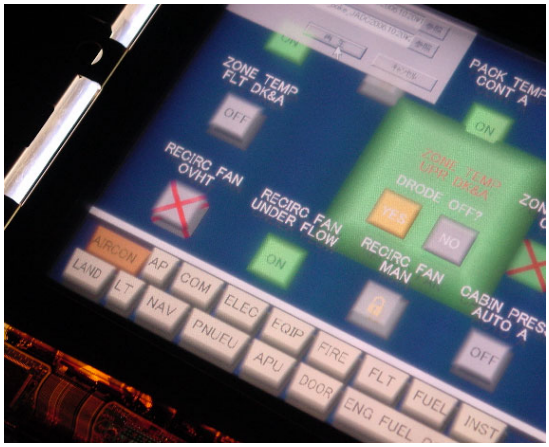


Fig.4 Touch Panel＋Diffusion Filter＋ Resolution Improvement Processing

Fig.5 Touch Panel＋Resolution Improvement Processing (Final Specification)

3 Test Product and Evaluation of UMC Control Display

3.1 Unit Function Test

Purpose of the unit function test is to acquire the physical characteristic data regarding basic display performance, and is to confirm indicatory operation function as UMC Control Display unit before the connection test.
Outline and the internal block diagram of the test product, are shown in Fig. 6 and Fig. 7.
The test product made only DFD and the LED back light part which have the development elements. A part for a graphic generator and the communications department was included in another computer for image generating.

Fig.6 Outline of Test Product

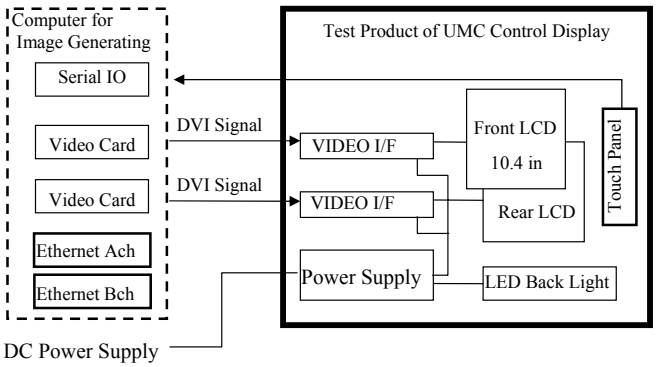


Fig.7 Internal Block Diagram of the Test Product

It was confirmed to satisfy numeric demands of the specification about physical characteristic data.
In addition, we verified that request is satisfied concerning indicatory operation function.

3.2 Environmental Test

The purpose of the environmental test is to confirm an environment to the temperature-altitude, the vibration, and the shock.
The reason which selects the test of these 3 types is because it was required as the test of DFD and the LED back light part which are the development elements.
The category of each examination is as follows.

- Temperature-Altitude
  DO-160E §4.0 Category A2
- Vibration
  DO-160E §7.0 Category B
- Shock
  DO-160E §8.0 Category R

The results of all tests were satisfactory.

3.3 Connection Test with UMC

Purpose of connection test is to confirm indicatory operation function as UMC Control Display by concatenating to UMC through Ethernet, and controlling real loads.
Fig. 8 and Fig. 9 show the photograph and connected block chart of the test.

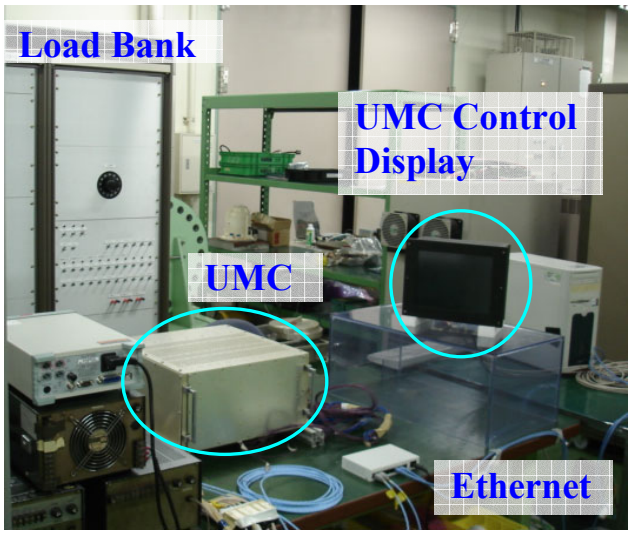


Fig.8 Photograph of Connection Test

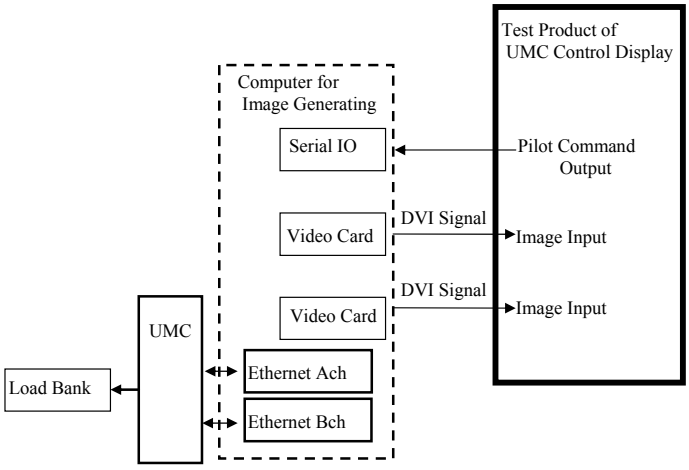


Fig.9 Connected Block Chart of the Test

As a result, we were able to confirm a state of each SSPC in UMC with UMC Control Display, and to confirm that we could reset the SSPC by inputting a reset command from UMC Control Display for SSPC which tripped.
In addition, we confirm that it is satisfactory concerning the operation at the time of data bus disconnection etc.

3.4 Recognition and Operativity Evaluation Test

In order to grasp the recognition and operativity of UMC Control Display system, we evaluated it by the pilots under the simulated flight environment that used the flight simulator.
Furthermore, we used a fixed wing flight simulator of JAXA for the evaluation test.
The examination item is divided into (1) arrangement layout evaluation, (2) recognition nature evaluation, and (3) operativity evaluation. Each pilot executed a series of task of recognizing SSPC tripped, and resetting the SSPC in the turbulence environment.
We evaluated it changing the arrangement in a cockpit of UMC Control Display by three pilots.

(1) As a result of arrangement layout evaluation, the pilots commented as follows. "The position of center console is the best and the position ahead of side console is good for the next." (Conducting of the examination as PNF(Pilot Not Flying))
(2) As a result of recognized evaluation and (3) operativeness evaluation, the pilots commented, "The situation assessment at trip became early compared with a conventional circuit breaker" and "The position of center console is best." (Conducting of the examination as PF(Pilot Flying))

The pilots commented, "There was no obstacle for the visual check and the operation in flight" about the moiré and the rear LCD resolution to try and error in 2.1.7.
Moreover, in discernment of a SSPC state, the pilots commented "The effect of a three-dimensional display is felt, and it is easy to identify especially in ground maintenance, and useful."

4 Conclusions

In the study of the Power Distribution System which aimed at the dispersion supply of electric power of the airplane power supply using SSPC, examination and trial production evaluated the UMC Control Display.

Moreover, as compared with the conventional circuit breaker, the comment that the circumstantial judgment at the time of a trip becomes early more was provided by using this equipment. The comment that discernment became easy by the 3D effect was provided also for ground maintenance crews.
Furthermore, we confirmed environmental adaptability to temperature-altitude, vibration and shock, and confirmed that the remote control and monitor of the power distributions were possible in the connection test with UMC.

References

[1] H. Takada, S. Suyama, K. Hiruma and K. Nakazawa, “A Compact Depth-Fused 3-D LCD,” SID’03 Digest of Technical Papers, 58.2, pp.1526-1529, Baltimore, MD, USA, May. 2003.

[2] “Design Objectives for Liquid Crystal Displays for Part 25 (Transport) Aircraft”, SAE ARP4256

[3] “Electronic Displays”, SAE ARP4102/7

Copyright Statement