Expanded Lineup and Improved Performance of MDU Breaker "W&WS Series"

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Mitsubishi Electric's contributions to energy conservation for reducing greenhouse gas emissions include the development of MDU breakers as energy-saving devices. The MDU breaker has a current transformer (CT) and a voltage transformer (VT) in the circuit breaker main body for measuring the load current, line voltage, electric power, electric energy, and other electric variables. The main features are listed below.

(1) Space-saving and easy to install
(2) High performance and multifunction

Recent years have seen an increased demand for more advanced energy management activities, such as the leveling of electric power load. Mitsubishi Electric has developed new models of the W&WS series that deliver higher performance. For enhanced usability, these models were designed with an emphasis on the following two aspects:

(1) Improvement of visibility
(2) Expansion of display functions

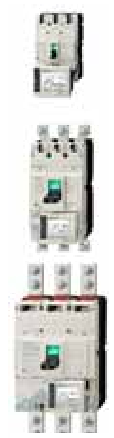
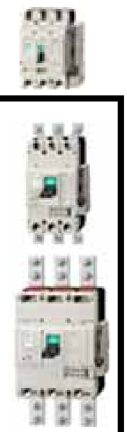
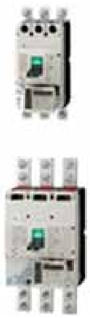
This paper describes the main features of the new models of the W&WS series along with several technical issues and their countermeasures.

1. Product models and features of the latest series

1.1 Product models

Table 1 shows the lineup. The newly added models (enclosed with the black lines in Table 1) can display their specification data in the panel openings (breaker

Table 1 Product lineup

	6-digit 7-segment LED display type		LCD type			
250A frame molded case circuit breaker			NF250-SEV/HEV with MDU			
400A frame molded case circuit breaker	NF400-SEP/HEP with MDU		Newly developed models	NF400-SEW/HEW with MDU		
630A frame molded case circuit breaker	NF630-SEP/HEP with MDU			NF800-SEW/HEW with MDU (300–630A)		
800A frame molded case circuit breaker	NF800-SEP/HEP with MDU			NF800-SEW/HEW with MDU (400–800A)	External mounting	Breaker mounting
Tolerance of main body measurement	· Load current and line voltage: ±2.5% (relative to the measurement rating) · Electric power: ±2.5% (relative to the measurement rating) · Harmonic current, leakage current, and leakage current containing harmonics: ±2.5% (relative to the measurement rating) · Electric energy: ±2.5% (rating: 5–100%, pf = 1) · Power factor: ±5.0% (relative to the electrical angle of 90°)		· Load current and line voltage: ±1.0% (relative to the measurement rating) · Electric power: ±1.5% (relative to the measurement rating) · Reactive power, harmonic current, leakage current, frequency, and leakage current containing harmonics: ±2.5% (relative to the measurement rating) · Electric energy: ±2.0% (rating: 5–100%, pf = 1) · Reactive energy: ±3.0% (rating: 10–100%, pf = 0) · Power factor: ±5.0% (relative to the electrical angle of 90°)			

*Fukuyama Works

mounting), in addition to the 250A frame LCD type. The external mounting type is made selectable when required, as with the 6-digit 7-segment LED display type.

1.2 Features of the latest MDU series

For enhanced usability, the visibility of the latest MDU breaker series was improved and the display functions were expanded.

1.2.1 Improvement of visibility

The latest models have LCDs with high-luminance white backlighting. Normal display (Fig. 1(a)) or color inversion (Fig. 1(b)) is selectable depending on the use environment.

1.2.2 Expansion of display functions

The display functions listed below were installed using the LCD function.

(1) Setting item list display function (only for external mounting)

This display function shows the setting items for the overcurrent tripping characteristics (to be set using the breaker main body) and others on the display (Fig. 2).

(2) Free item display function (only for external mounting)

The free item display function enables the registration of all necessary measurement items to be displayed (Fig. 3).

(3) Three-phase (four-phase) display function

A display function for each phase of the measurement items (current and voltage) is provided (Fig. 4). In addition, the screen orientation can be changed as a specification when a breaker is installed in the horizontal direction.

(4) Function for displaying red backlight when an alarm is issued

The backlight color when an alarm is issued has been changed to red to make it easier to notice an error from a distance (Fig. 5). In addition, the display format for the red backlight (lighting up or blinking) can be selected as a specification.

2. Technical issues and their countermeasures

2.1 Improvement of the design efficiency of LCD backlight

To improve the visibility of the LCDs, a backlight with light guide plates was adopted. Two types of backlight – white and red – are used. Simulation was carried out to reduce the trial and error process, which made it possible to efficiently design a backlight with high and even luminance. Specifically, the incident end face and surface shape of the light guide plate, the mounted location and required number of backlight LEDs, the shape of the reflection and diffusion sheets, and other conditions were changed to identify those that produced a high and even luminance over the entire LCD.

Figure 6 shows the simulation results. Figure 7 shows a circuit board with backlight LEDs mounted and a light guide plate.

(a) Normal display (three-phase display)

(b) Color inversion (three-phase display)

Fig. 1 LCD display screen

Pressing the up or down button displays the following items:
- Setting of long time delay trip (LTD)
- Setting of short time delay trip (STD)
- Setting of instantaneous trip (INST)

Fig. 2 LTD setting value screen of setting item list display function

This indicates that this is Page 1.

- One screen can show two items.
- Four pages are provided for the free item display screen. (Up to eight items can be registered.)

Fig. 3 Free item display screen

Fig. 4 Three-phase display screen

Fig. 5 Red backlight indication at alarm occurrence

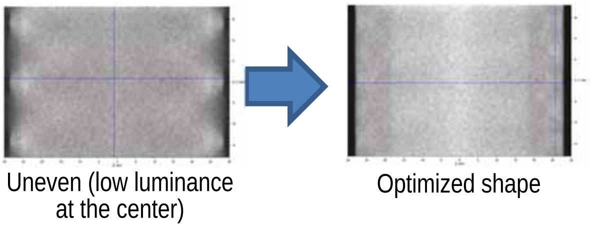


Fig. 6 Simulation results of backlight design for LCD

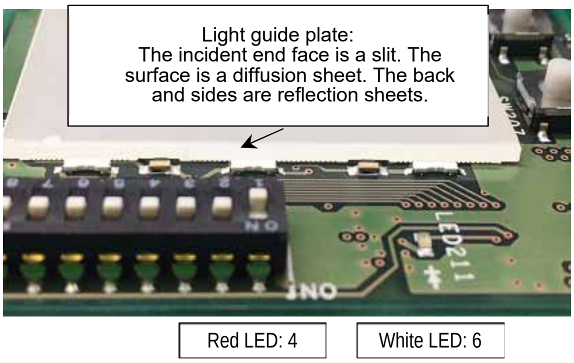


Fig. 7 LED mounting board for backlight and light guide plate

2.2 Front loading for countermeasures against EMI

Electrical noise emitted from electrical equipment propagates through space or wireways and may affect the operation of other electrical equipment and radio equipment, so the emission levels need to be equal to or lower than the standard values. For products with many restrictions on the mounting area, in particular, a revision (e.g., addition or change of parts and change of circuit board patterns) in the evaluation phase, which is a later stage of development, requires redesigning under many restrictions along with reevaluation due to the revision, greatly affecting the development schedule. This section describes front loading performed in the circuit design and circuit board design phases (early stages of the development) for countermeasures against conducted and radiated noise.

2.2.1 Front loading for countermeasures against conducted noise

(1) Consideration of circuit analysis models

The noise level must be reduced to that equal to or lower than the standard value by a noise filter circuit (CR passive filter) in the power circuit input stage installed as a countermeasure against conducted noise. Since there are many restrictions on mounting, a revision to the circuit due to the addition of a filter stage and other reasons requires heavy reworking, which may delay the delivery date. Therefore, we focused on the fact that the switching transformer of the power circuit is the propagation path of normal noise and common noise that are the cause of conducted noise: a simulation was performed using a circuit analysis model with a high-accuracy equivalent circuit of the switching transformer to evaluate the circuit. Figure 8 illustrates the equivalent circuit of the switching transformer.

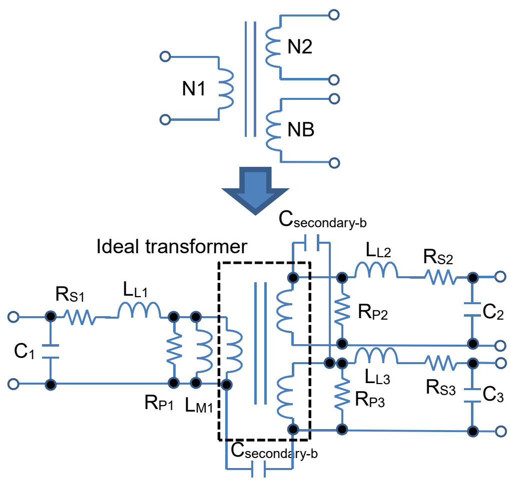
For the equivalent circuit constants of the switching transformer (e.g., leakage inductance and winding stray capacitance), the values were calculated by measuring the impedance of the parts adopted.

(2) Simulation results and measured data

The high-accuracy equivalent circuit analysis model was used for simulation in the early design stage to determine the number of filter stages and the constants of the parts such that the noise level would be reduced to the standard value or lower, where the carrier frequency (fc) of the switched mode power supply was 75 kHz (design value). Next, prototypes were fabricated based on these circuit conditions and they were used to measure the noise level. The evaluation results were excellent. In other words, front loading in which high-accuracy simulation is performed in the early design stage to check the necessary filter configuration, reduced the development period. Figure 9(a) shows the simulation results of the conducted noise. Figure 9(b) shows the measurement results using an actual product.

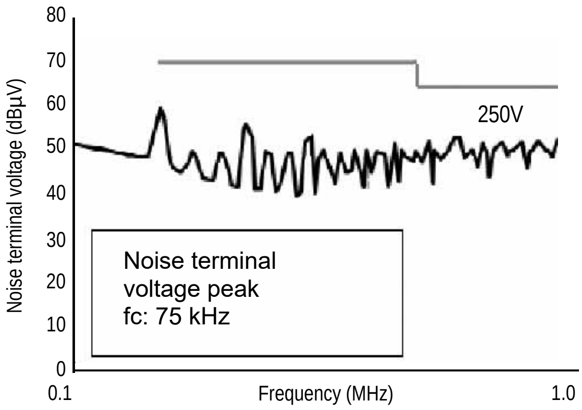
2.2.2 Front loading for countermeasures against radiated noise

As countermeasures against radiated noise,

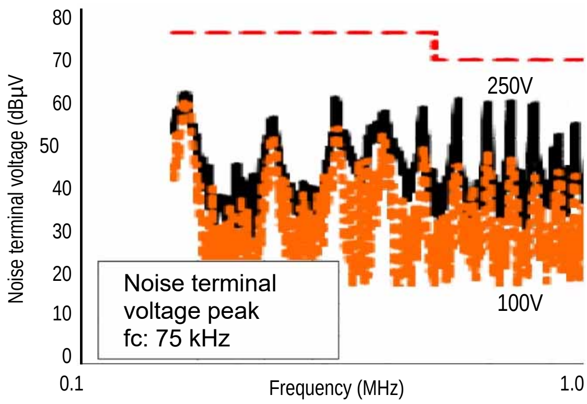


L_{M1}	Primary magnetizing inductance
L_{L1}	Primary leakage inductance
L_{L2}	Secondary leakage inductance
L_{L3}	Bias winding leakage inductance
R_{S1}	Primary winding copper loss component
R_{S2}	Secondary winding copper loss component
R_{S3}	Bias winding copper loss component
C_1	Capacity between primary winding lines
C_2	Capacity between secondary winding lines
C_3	Capacity between bias winding lines
R_{P1}	Primary magnetic loss component
R_{P2}	Secondary magnetic loss component
R_{P3}	Bias winding magnetic loss component
$C_{primary\text{-}b}$	Primary-bias winding stray capacitance
$C_{secondary\text{-}b}$	Secondary-bias winding stray capacitance

Fig. 8 Equivalent circuit of switching transformer

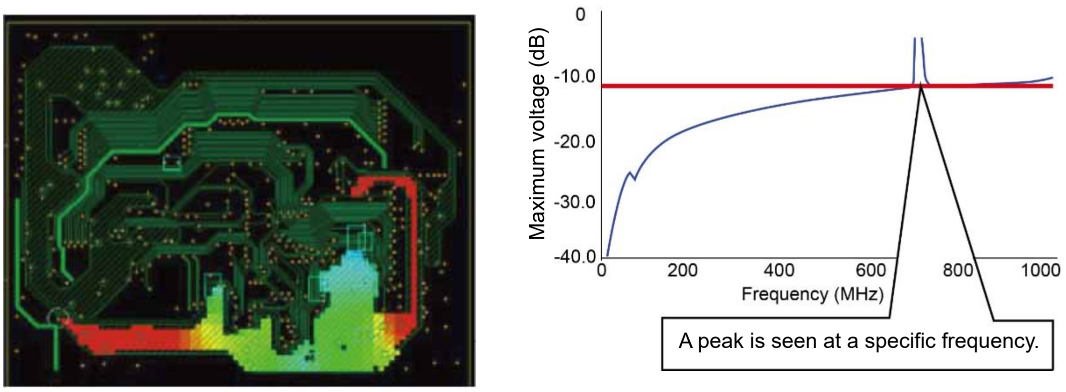


(a) Simulation results

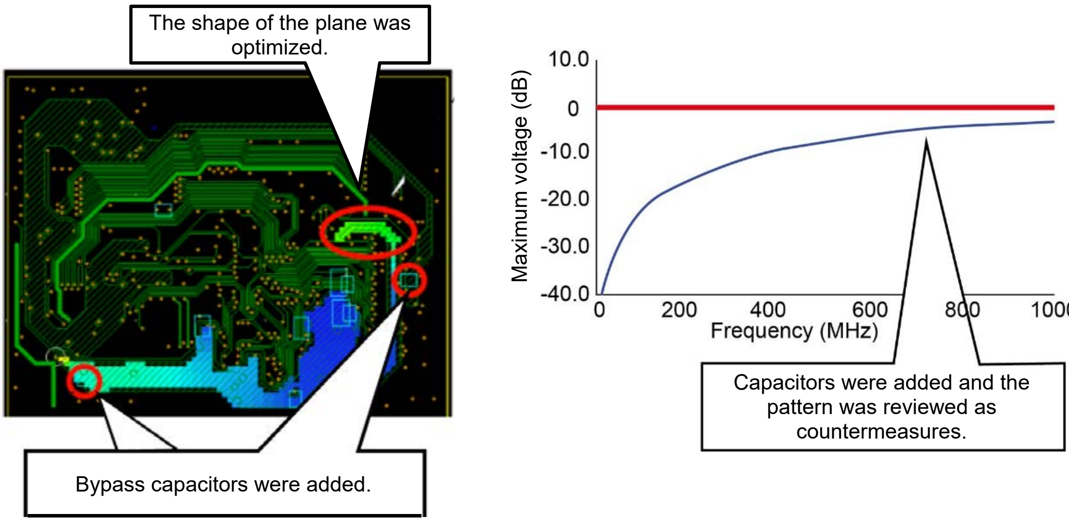


(b) Measurement results using an actual product

Fig. 9 Evaluation of conducted noise



(a) Before countermeasures



(b) After countermeasures

Fig. 10 Results of substrate resonance analysis of radiated noise

resonance between a power supply and ground plane that could generate radiated noise was analyzed in the circuit board design phase to optimize the shape from the power supply to the ground plane. In addition, it was determined to add bypass capacitors. This achieved the design to suppress the peak at a specific frequency and reduce the noise voltage level to the standard value or lower. Figure 10 shows the analysis results of the resonance of circuit boards before and after the countermeasures against radiated noise.

3. Conclusion

This paper described the features of the latest MDU breaker models along with several technical issues and their countermeasures. We will continue developing high-quality products that meet user needs.