Application Note

Automatic partial discharge (RPDIV) using impulse voltages as defined in IEC 61934

With conventional impulse testers, it is difficult to automatically perform partial discharge (RPDIV) testing as defined in IEC 61934. Sequence Maker, a free Excel add-in, quickly creates programs that make it possible to automate such testing.

Target

EV motors, motors in inverter-equipped household appliances, air-conditioner compressors, industrial motors, industrial pumps, etc.

Market Movements

Inverters and motors are transitioning to high drive (switching) voltages. EVs use drive voltages of up to 800 V, while the drive voltages used by some inverter-equipped household appliances such as washing machines, air conditioners, and refrigerators range from 400 V to in excess of 600 V. Generally speaking, partial discharges occur when there is a voltage difference of greater than 350 V to 400 V. With general-purpose inverters, the problem of partial discharges becomes conspicuous for motors when the primary-side voltage reaches 400 VAC.

Additionally, high-speed switching operation of inverters produces surge voltages of more than double the switching voltage. These surge voltages make partial discharges even more likely. (Fig.1)

The IEC 61934 standard defines a procedure for partial discharge testing using impulse voltages. This testing regime measures PDIV, RPDIV, RPDEV, and PDEV.
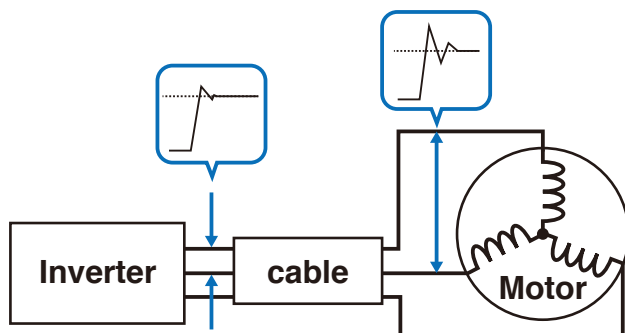

Fig.1　Surge voltage at the edge of a motor

Application Note

Problem

IEC 61934 defines the following test procedure:

- Determine the minimum test voltage at which no partial discharge is detected as well as the maximum test voltage at which a partial discharge is always detected.
- Progressively raise the test voltage while applying each same test voltage multiple times (for example, 10 times).
- The first impulse voltage at which a partial discharge is detected is PDIV.
- The impulse voltage at which a partial discharge is detected 5 out of the 10 applications is RPDIV.
- Progressively lower the test voltage from the maximum test voltage to the minimum test voltage.
- The minimum voltage at which 5 partial discharges are detected is RPDEV.
- The impulse voltage at which partial discharges are no longer detected is PDEV.

With conventional impulse testers, it is difficult to automatically perform partial discharge (RPDIV) testing as defined in IEC 61934.
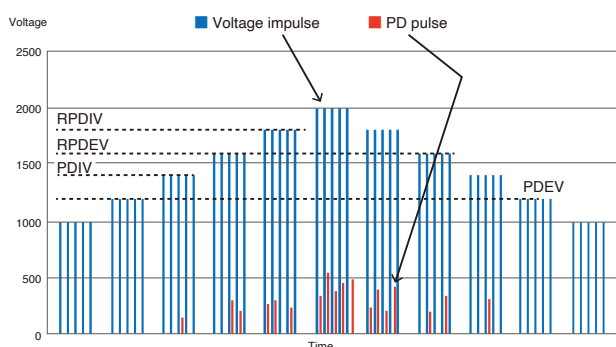

Fig.2 IEC61934 Test procedure

Solutions

Hioki programmed a sequence that can perform the IEC 61934 test procedure using Sequence Maker (an Excel add-in) and used it to control an ST4030A Impulse Winding Tester. A sequence of commands corresponding to buttons on the instrument can be created in the order of button operation, and data receive commands can be executed to receive the data in Excel. In this way, it is possible to create a program in a short period of time. (See Figs. 3 and 4.)

Fig.3 Sequence Maker program

Application Note
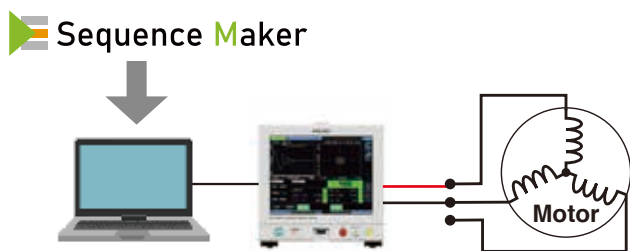
Fig.4 Connection diagram

Equipment used

IMPULSE WINDING TESTE	ST4030A	HIOKI
Sequence Maker		HIOKI

Measured data

Measurement yielded the following results: PDIV = 1700 V, RPDIV = 2150 V, RPDEV = 2100 V, and PDEV = 1950 V.

The test voltages were initially set in 100 V increments, but the results indicated that the interval was too large. RDIV was detected right away, without detecting PDIV. The partial discharge (PD) threshold value was determined to be $\sigma \geqq 6$.

Fig. 5 provides a graph of the results.

Set voltage [V]	PD count	1 Peak [V]	1 PD [σ]	2 Peak [V]	2 PD [σ]	3 Peak [V]	3 PD [σ]	4 Peak [V]	4 PD [σ]	5 Peak [V]	5 PD [σ]	6 Peak [V]	6 PD [σ]	7 Peak [V]	7 PD [σ]	8 Peak [V]	8 PD [σ]	9 Peak [V]	9 PD [σ]	10 Peak [V]	10 PD [σ]
1,500	0	1,497.34	2.45	1,494.40	2.46	1,502.87	3.84	1,497.60	2.72	1,498.64	2.59	1,499.32	2.19	1,498.54	3.1	1,498.82	3.31	1,497.67	2.36	1,499.20	3.52
1,550	0	1,546.43	2.5	1,543.28	2.68	1,552.10	2.99	1,547.78	2.26	1,549.13	2.68	1,548.22	1.99	1,548.87	2.38	1,548.14	4.6	1,549.45	3.38	1,548.63	2.27
1,600	0	1,595.56	2.74	1,594.72	2.43	1,602.35	4.15	1,597.28	2.46	1,598.91	2.78	1,597.79	3.21	1,598.46	3.4	1,599.10	3.39	1,598.24	2.93	1,599.20	5.42
1,650	0	1,649.06	2.64	1,646.03	4.15	1,654.29	3	1,649.84	4.29	1,651.93	3.04	1,651.05	4.12	1,651.10	3.06	1,651.13	3.52	1,650.95	2.94	1,649.96	2.47
1,700	1	1,696.98	2.97	1,693.29	3.89	1,700.81	2.44	1,698.99	2.76	1,699.82	2.73	1,700.46	2.76	1,699.92	3.4	1,699.41	4.12	1,698.99	7.89	1,698.49	2.49
1,750	0	1,745.14	4.73	1,744.36	3.01	1,752.96	3.01	1,748.67	2.5	1,749.41	2.65	1,749.21	2.65	1,748.60	3.04	1,750.47	3.08	1,749.50	3.41	1,749.33	2.9
1,800	1	1,795.33	2.3	1,795.22	2.66	1,805.55	3.1	1,800.64	2.76	1,799.40	3.06	1,800.66	3.28	1,800.35	2.27	1,799.49	3.26	1,799.97	7.38	1,801.30	3.42
1,850	1	1,846.35	6.82	1,842.34	3.11	1,852.42	3.17	1,847.52	2.78	1,849.31	2.78	1,852.35	2.94	1,847.42	5.86	1,849.72	3.71	1,849.54	2.69	1,849.81	2.26
1,900	1	1,895.00	2.6	1,894.31	8.95	1,903.63	3.09	1,899.38	2.6	1,898.26	2.58	1,897.10	3.03	1,900.02	2.74	1,899.50	3.44	1,897.60	2.4	1,899.94	2.25
1,950	0	1,945.62	3.02	1,945.85	2.53	1,954.90	2.23	1,947.29	3.45	1,950.77	3.27	1,949.01	3.95	1,951.38	3.02	1,950.88	2.56	1,947.73	2.91	1,949.38	3.14
2,000	0	1,992.79	3.08	1,991.23	2.49	2,000.79	3.19	1,995.29	2.77	1,997.89	2.8	1,997.82	3.1	1,996.60	5.06	1,996.61	2.86	1,996.85	3.38	1,995.75	2.64
2,050	1	2,047.39	2.98	2,044.78	2.63	2,055.14	2.97	2,049.30	17.7	2,051.08	4.46	2,049.23	3.84	2,050.81	4.04	2,050.20	2.38	2,050.96	2.76	2,048.83	2.74
2,100	3	2,096.63	16.77	2,096.47	3.74	2,106.01	21.39	2,100.89	16.79	2,101.18	2.74	2,099.98	4.26	2,101.44	3.09	2,100.42	3.09	2,099.95	2.35	2,101.11	2.74
2,150	5	2,147.18	22.58	2,149.78	3.33	2,154.19	3.41	2,151.86	8.67	2,152.33	2.9	2,152.91	20.63	2,152.87	5.96	2,151.20	4.14	2,152.37	22.64	2,152.37	19.83
2,200	2	2,199.42	3.07	2,194.08	3.87	2,204.22	3.2	2,197.76	3.05	2,201.34	3.16	2,200.03	3.99	2,200.39	3.79	2,202.11	3.76	2,199.90	21.63	2,201.01	19.91
2,250	6	2,247.40	23.86	2,246.20	34.13	2,249.86	20.79	2,250.10	3.86	2,250.46	25.47	2,251.50	21.37	2,249.75	5.92	2,252.19	5.96	2,250.42	3.68	2,251.50	6.11
2,300	5	2,297.13	3.51	2,297.56	24.48	2,303.46	4.2	2,297.70	6.85	2,301.00	27.24	2,300.22	14.09	2,300.04	3.22	2,295.42	3.43	2,299.92	14	2,300.25	3.89
2,350	10	2,350.01	26.19	2,346.80	25.41	2,351.42	13.15	2,349.20	16.85	2,349.29	17.59	2,349.98	18.35	2,353.01	18.75	2,352.01	17.44	2,350.34	21.9	2,349.00	19.49
2,400	10	2,401.38	21.04	2,400.06	16.05	2,403.61	15.99	2,400.82	17.04	2,402.57	16.32	2,399.01	16.21	2,399.34	19.89	2,402.35	17.63	2,401.04	19.14	2,401.59	17.87
2,350	10	2,348.68	25.94	2,348.21	23.98	2,353.01	23.47	2,348.62	26.32	2,350.20	25.08	2,349.20	24.65	2,349.84	26.35	2,348.89	25.22	2,350.76	24.84	2,351.05	24.58
2,300	10	2,297.73	23.2	2,297.43	20.41	2,301.32	24.76	2,301.08	24.44	2,301.75	21.44	2,301.18	22.5	2,299.29	25.93	2,301.74	20.62	2,301.01	23.49	2,299.37	28.04
2,250	9	2,249.02	25.65	2,248.74	3.55	2,252.13	19.95	2,247.89	22.42	2,249.79	23.98	2,250.55	21.3	2,249.99	19.92	2,250.66	21.92	2,247.99	22.42	2,251.63	24.47
2,200	9	2,197.37	24.85	2,196.03	22.06	2,202.09	20.46	2,199.04	19.76	2,199.59	22.77	2,201.27	20.37	2,202.01	4.51	2,201.80	16.86	2,201.22	22.99	2,203.33	21.86
2,150	4	2,146.17	4.41	2,146.62	19.66	2,153.05	16.26	2,152.00	16.49	2,150.93	4.61	2,151.99	3.63	2,151.62	3.42	2,147.91	3.4	2,150.72	17.43	2,148.81	4.5
2,100	5	2,100.29	18.17	2,097.16	3.24	2,102.25	3.38	2,101.98	19.3	2,100.89	3.06	2,101.43	2.98	2,101.64	15.54	2,102.47	20.49	2,100.50	2.65	2,101.00	20.67
2,050	2	2,044.27	3.34	2,043.51	3.1	2,049.26	12.68	2,047.33	2.4	2,048.26	15.45	2,048.08	4.59	2,047.38	2.46	2,046.84	3.41	2,049.32	2.85	2,047.51	3.11
2,000	3	1,996.88	3.22	1,992.66	15.21	1,999.55	5.56	1,997.57	3.54	1,999.76	16.31	1,996.04	4.5	1,998.48	16.6	1,996.02	3.37	1,997.17	2.5	1,998.89	2.58
1,950	0	1,946.25	2.89	1,945.33	2.75	1,952.83	2.69	1,950.54	3.75	1,950.74	2.67	1,948.77	2.67	1,951.00	2.88	1,950.47	3.46	1,950.18	2.5	1,948.66	2.99
1,900	0	1,897.50	2.65	1,892.82	3.1	1,902.62	2.6	1,897.33	3.15	1,897.75	2.39	1,899.72	2.65	1,899.34	2.57	1,898.80	2.64	1,899.63	2.79	1,899.47	3.22
1,850	0	1,848.15	3.14	1,843.95	2.26	1,852.46	2.79	1,847.62	2.49	1,850.34	2.7	1,850.20	2.7	1,849.52	2.7	1,850.22	2.59	1,848.91	2.41	1,848.71	2.53
1,800	0	1,796.31	2.86	1,795.07	4.59	1,805.63	3.5	1,802.03	2.41	1,802.03	2.43	1,800.12	3.1	1,800.96	3.08	1,799.86	4.43	1,800.61	2.54	1,799.98	2.44
1,750	0	1,746.45	3.01	1,744.46	3.2	1,755.08	2.36	1,748.98	2.43	1,750.64	2.7	1,749.69	3.54	1,749.77	3.33	1,751.44	2.51	1,750.47	2.87	1,750.55	5.65
1,700	0	1,697.53	3.27	1,693.56	3.51	1,703.02	2.69	1,699.06	3.42	1,700.68	3.56	1,700.19	4.36	1,699.78	2.48	1,699.21	2.73	1,699.68	2.83	1,699.19	3.16
1,650	0	1,645.58	3.03	1,647.47	2.91	1,654.23	2.98	1,650.45	2.86	1,649.82	2.51	1,650.00	5.45	1,649.62	3.13	1,649.42	2.87	1,649.97	2.51	1,650.02	3.89
1,600	0	1,595.91	3.52	1,595.31	2.52	1,605.12	2.81	1,598.79	2.96	1,602.98	2.76	1,601.83	2.47	1,600.94	3.88	1,600.08	2.8	1,600.93	3.19	1,601.13	3.39
1,550	0	1,546.45	2.62	1,545.66	2.3	1,553.71	3.13	1,550.39	2.71	1,551.25	3.04	1,549.22	2.34	1,548.97	2.42	1,549.10	2.77	1,550.02	2.55	1,550.37	3.21
1,500	0	1,497.47	2.66	1,494.79	2.46	1,504.56	2.64	1,499.14	2.47	1,499.47	2.65	1,499.67	3.08	1,500.19	2.93	1,499.84	2.41	1,499.39	3.02	1,499.46	3.6

Table 1 Impulse voltage versus partial discharges
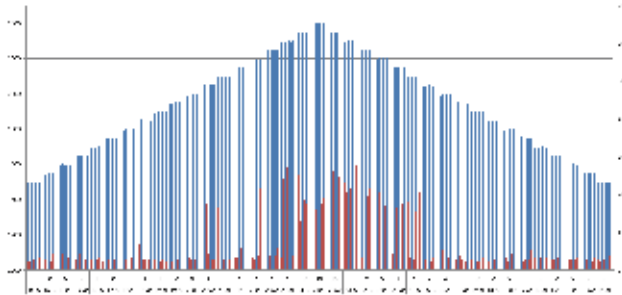
Application Note

Fig.5 IEC61934 test results

Summary

● Sequence Maker can be used to automatically measure the PDIV, RPDIV, RPDEV, and PDEV impulse voltages according to the test procedure defined by IEC 61934.
● Since Sequence Maker is an Excel add-in, it only requires users to memorize how to use commands in order to easily create sequence programs.

Application precautions:

· The application can be used to control the ST4030 and ST4030A.
· The ST4030 and ST4030A's firmware must be updated.
· Sequence Maker can be downloaded free of charge from the following
  URL : https://www.hioki.com/global/support/download/software/versionup/detail/id_609
· Sequence Maker can also be downloaded from the URL provided in the User Manual.
· Please contact a Hioki salesperson if you require a sample program.