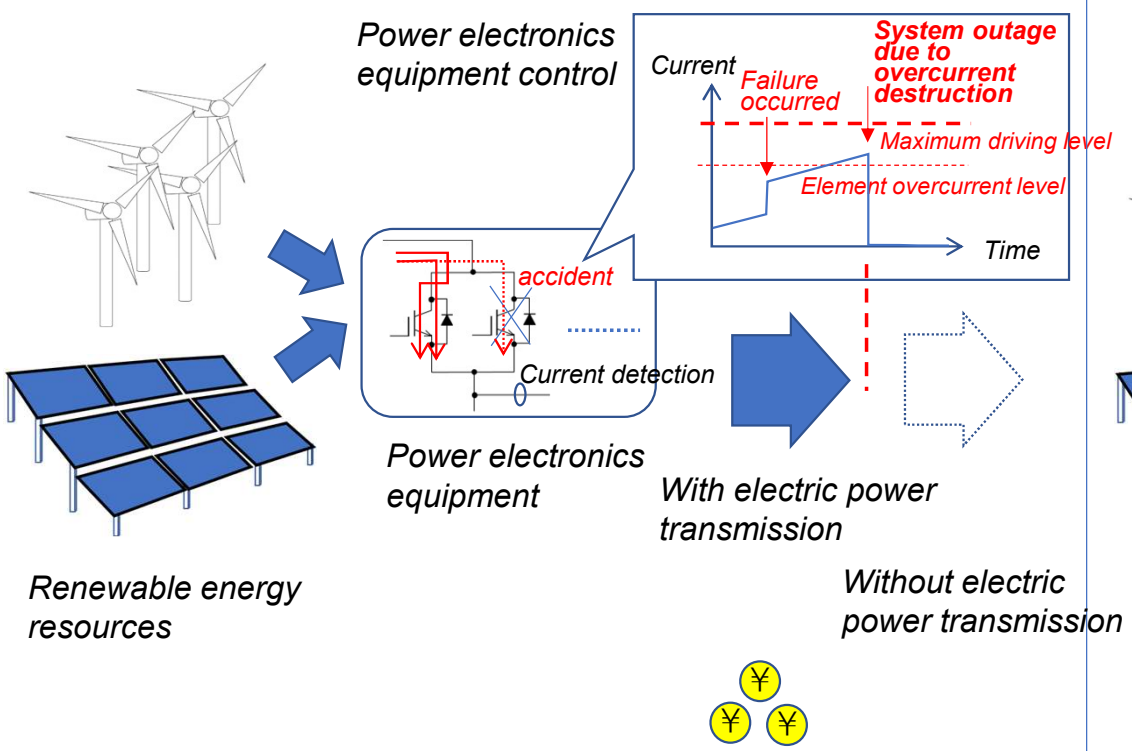
3. Research on abnormality diagnosis technology for power electronics equipment using machine learning

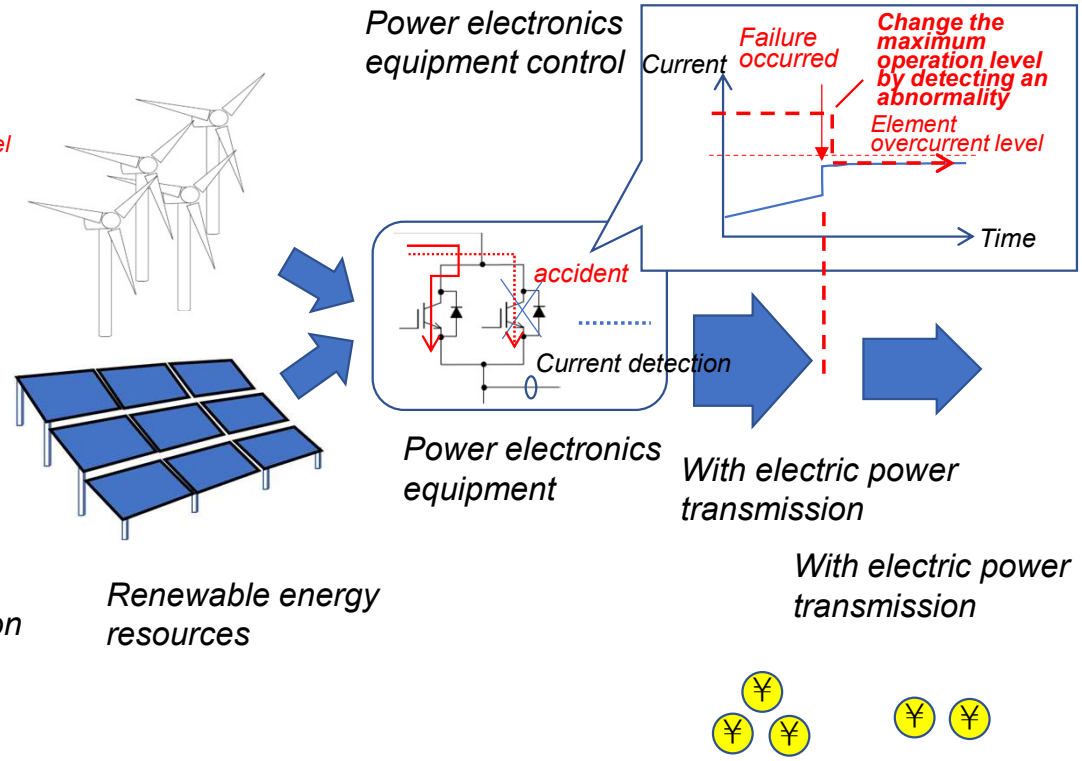
①王，中嶋，原田，浦壁,
「機械学習によるDC/DCコンバータの異常診断」, 令和4年電気学会全国大会,
WEB15-A3 パワーエレクトロニクス DC-DC変換（非絶縁） 4-038 （2022）
②王，原田，浦壁,
「機械学習を活用したDC/DCコンバータの異常診断技術の検討」,
電気学会研究会資料（半導体電力変換／モータドライブ合同研究会）,
SPC-23-023/MD-23-023（2023）

Purpose: Realization of abnormality diagnosis technology for power electronics equipment utilizing machine learning that does not require deep specialized knowledge or the addition of many measuring instruments with the aim of improving the continuity of operation of electric power and mobile equipment.

Conventional power system (None abnormality diagnosis)



Future power system (with abnormality diagnosis)



Advantages of abnormality diagnosis function + power electronics control

1. Using the machine learning method SVM, the diagnosis of abnormalities in DC/DC converter components is verified by simulation. Four states are identified using output voltage waveform data with time resolution of 80k~800kHz (5) and voltage resolution of 8~14bit (7).

(1)Verification conditions

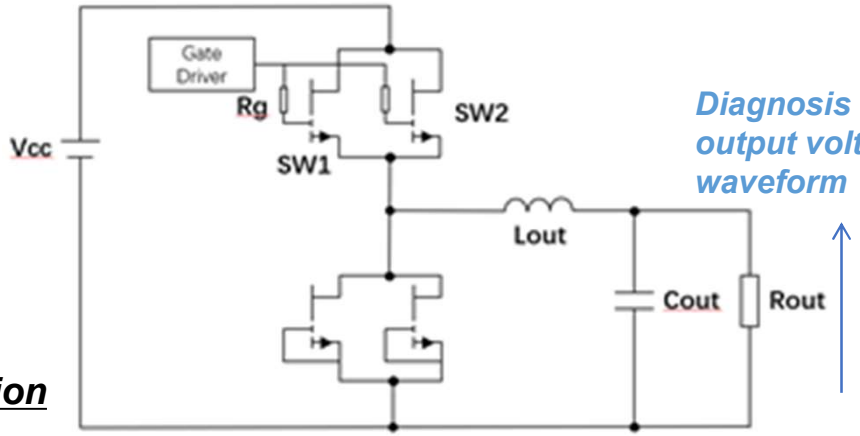


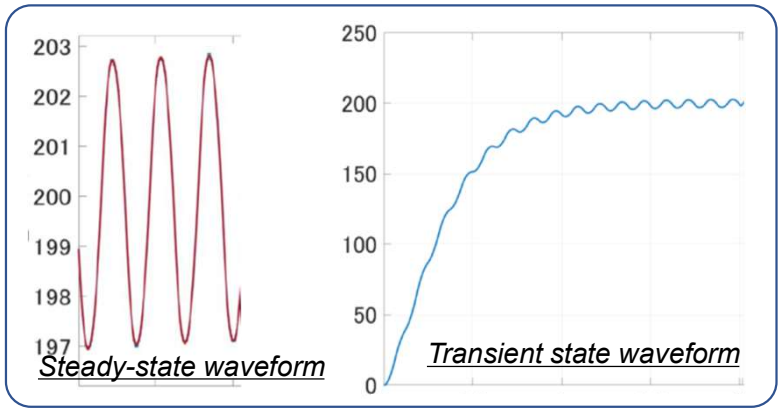
Figure 1. Circuit configuration

Table 1. Circuit parameters for the four states

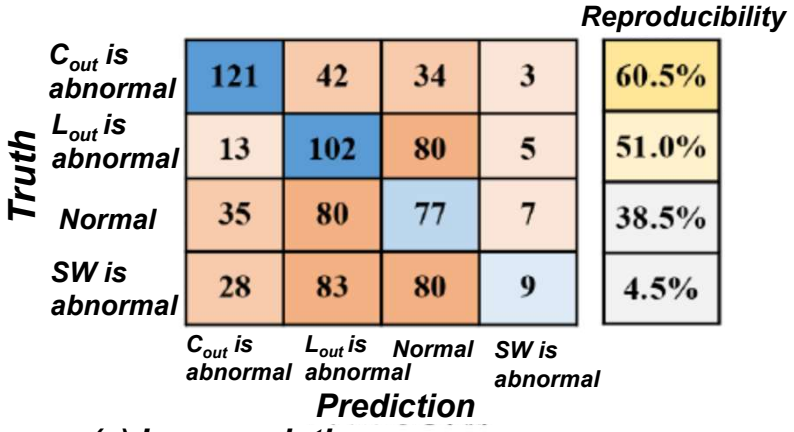
	SW	Lout	Cout
All normal	*SW1: Action SW2: Action*	*800 μH±5 %*	*0.47 μF±5 %*
Only SW is abnormal	*SW1: Action SW2: Stop*	*Normal*	*Normal*
Only Lout is abnormal	*Normal*	*800 μH -50 % ~ -6 % +6 % ~ +10 %*	*Normal*
Only Cout is abnormal	*Normal*	*Normal*	*0.47 μF -50 % ~ -6% +6 % ~ +10%*

Table 2. Other circuit parameters

	Steady-state waveform	Transient state waveform
Vcc	*400V±5%*	
SW1, SW2	*GaN HEMT GS66516B model*	
Rg	*2Ω±5%*	
Rout	*20Ω±5% (Load)*	*1kΩ±5% (Resistance to discharge)*
SW frequency・Duty・Gate Voltage	*80kHz,Duty50% Vgs=6V*	*80kHz,Duty10% Vgs=6V*
The number of data	*4000 (Teacher 3200/Examination 800)*	

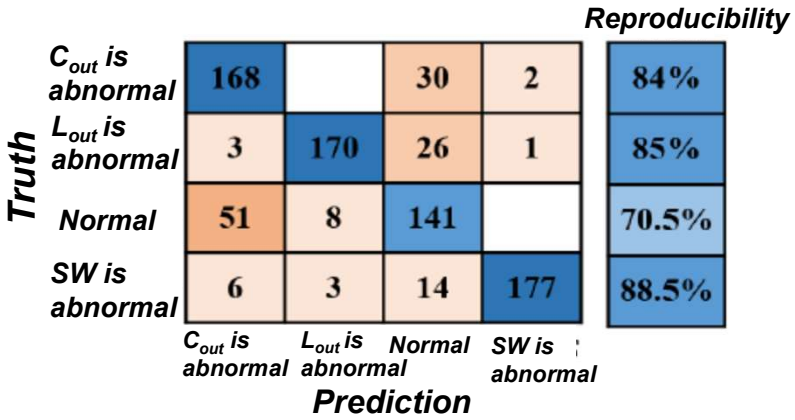


(2) Verification Results (Confusion matrix and reproducibility of the four states)



(a) Low resolution

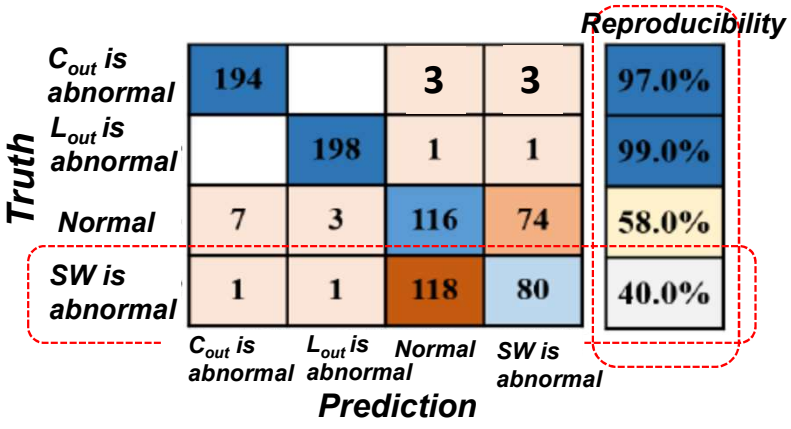
Time resolution 80kHz / Voltage resolution 8bit



(b) High resolution

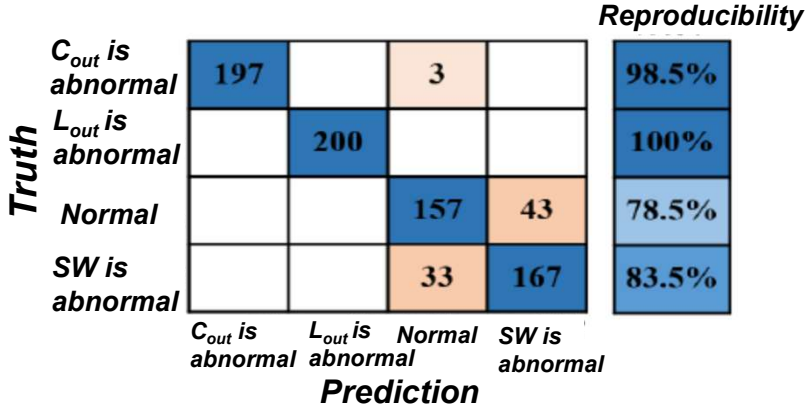
Time resolution 800kHz / Voltage resolution 14bit

Figure 1. confusion matrix and reproducibility of the four states (Waveforms of steady state)



(a) Low resolution

Time resolution 80kHz / Voltage resolution 8bit



(b) High resolution

Time resolution 800kHz / Voltage resolution 14bit

Figure 2. confusion matrix and reproducibility of the four states (Waveforms of transient states)

Total Reproducibility

$$73.5\%\left(=\frac{194+198+116+80}{200\times 4}\right)$$

Reproducibility of SW anomaly

$$40\% = \frac{80}{200}$$

*Steady-state waveforms cannot be diagnosed at low resolution.
*Transient state waveforms can be diagnosed with high accuracy at low resolution for C and L.
*A method to diagnose SW anomalies at low resolution is needed.

2. Using the machine learning method SVM, the diagnosis of abnormalities in DC/DC converter components is verified by simulation. We propose a method with high discrimination accuracy under low detection resolution conditions.

(1) Verification conditions

①*Simulation circuit: Same as 1.(1)*
②*Four conditions to diagnose: Same as 1.(1)*
③*Diagnostic waveform:*
Output voltage in transient state
④*Other conditions*

Vcc	400V±5%
SW1，SW2	GaN HEMT GS66516Bのモデル
Rg	2Ω±5%
Rout	1kΩ±5%（放電抵抗）
ゲート信号	80kHz,Duty10% **Vgs=1.5V**
分解能毎の波形の数	4000（教師3200/試験800）

(2) Verification results (Total reproduction rate for 4 conditions)

	80kHz (1(*2))	160kHz (2)	240kHz (3)	400kHz (5)	800kHz (10)
8bit(391mV(*1))	98.8%	99.0%	98.6%	98.4%	99.4%
9bit(195mV)	98.9%	99.4%	99.3%	99.3%	98.1%
10bit(98mV)	99.3%	99.5%	99.6%	99.4%	99.0%
11bit(49mV)	99.8%	99.5%	99.5%	99.8%	99.5%
12bit(24mV)	99.4%	99.5%	99.9%	99.3%	99.3%
13bit(12mV)	99.6%	99.5%	99.5%	99.5%	99.4%
14bit(6mV)	99.8%	99.5%	99.5%	97.6%	99.6%

*(*1) Voltage for 1 bit*
*(*2) Ratio to carrier frequency*

**Highly accurate diagnosis is possible by setting the transient state waveform and gate drive voltage to 1.5V (near threshold).*