

No. 36 Turbomachinery Symposium

Case Study 01

***The Torsional Torque Fluctuations
of a Compressor Train with a
Vector Control PWM Inverter***

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Objective

1. Background

1) Motor driven Compressor Train

2. Adjustable Speed Drive System

3. Accident

1) Diagnostic of Accident

2) Specification of Motor equipment

3) Motor Speed Control Method

4) Site Measurement

4. Study – Inverter

5. Site Measurement after Modification

6. Conclusion

Abstract

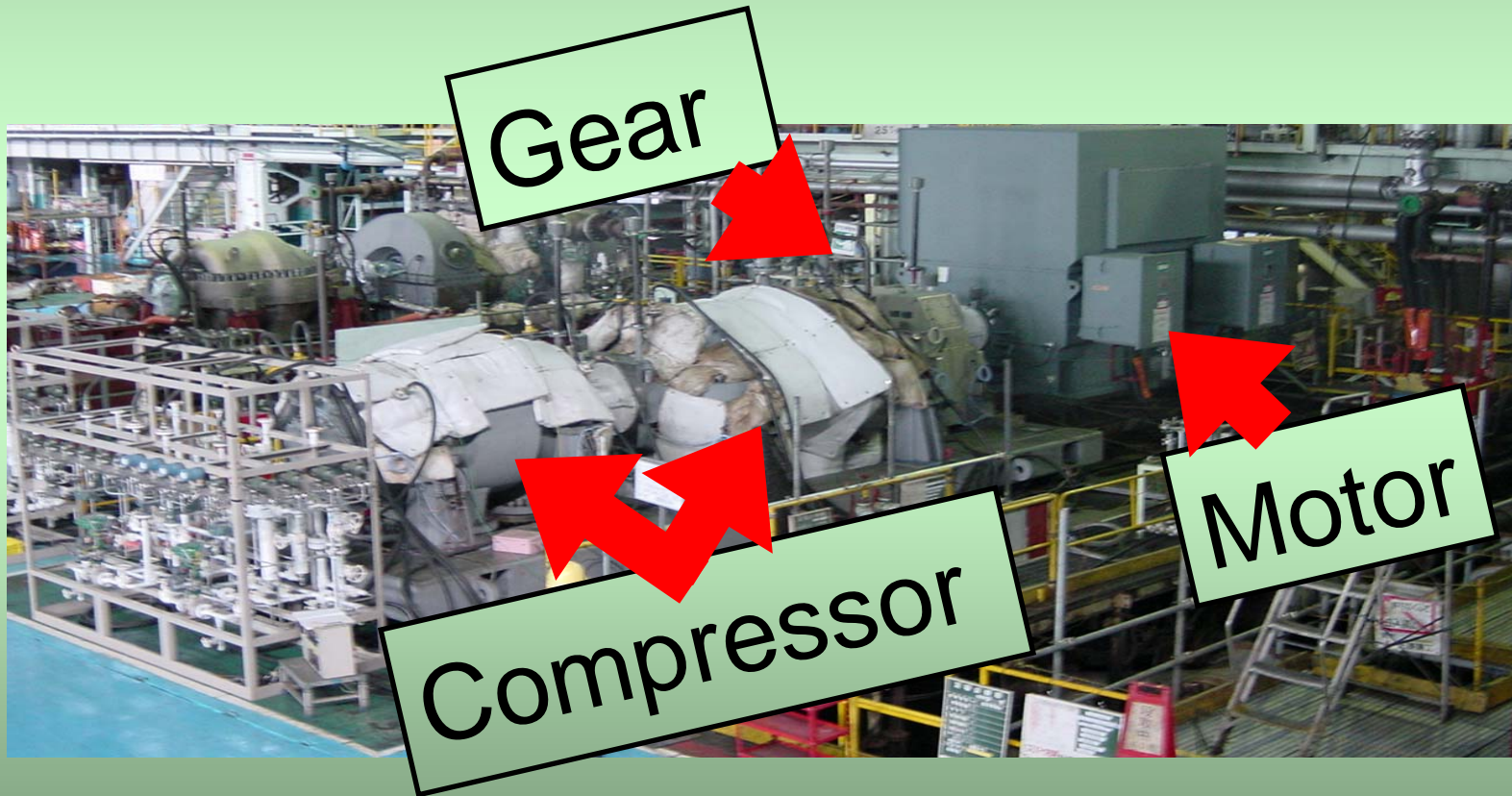
◆ A stable speed & torque control system is essential for large adjustable speed motor driven compressor trains.

In order to achieve stable control, advanced control techniques are required.

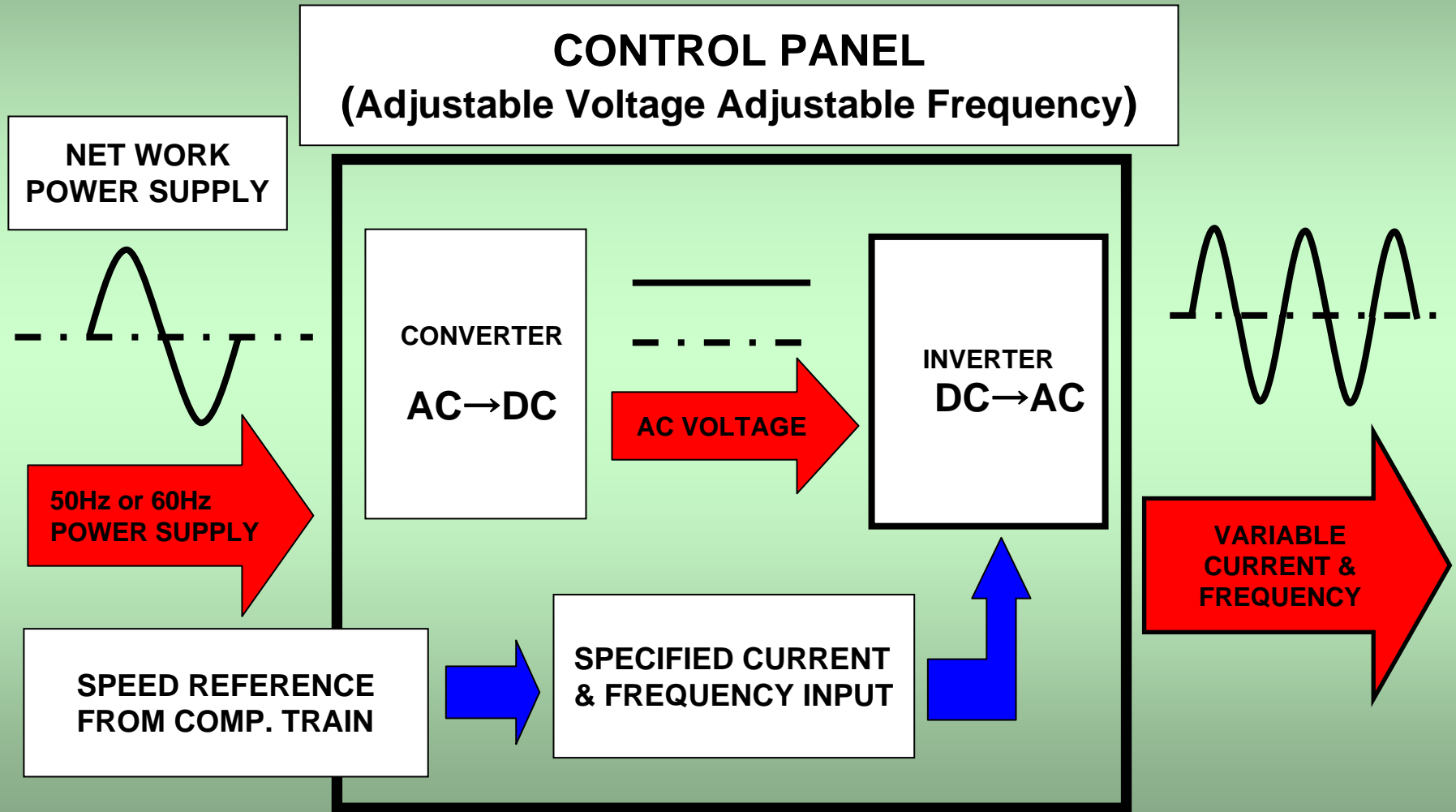
This case study shows the problems associated with & the countermeasures taken relating to the adjustable speed drive control.

Investigation, simulation and a successful resolution of the problem achieved safe & stable compressor operation.

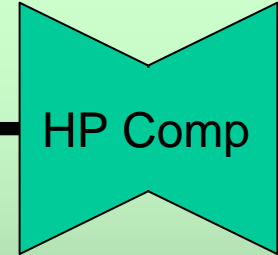
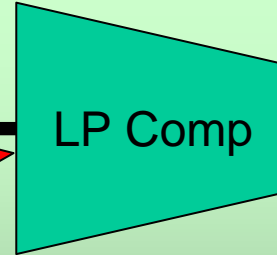
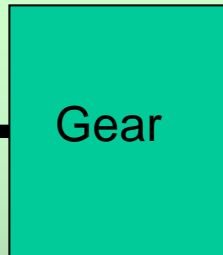
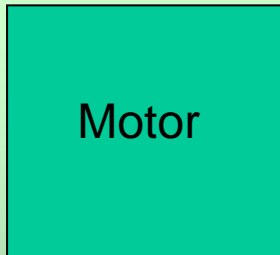
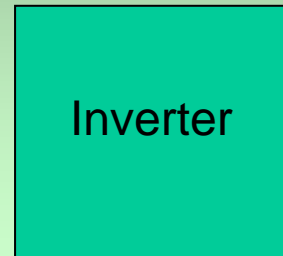
Motor driven Compressor Train



Adjustable Speed Drive System



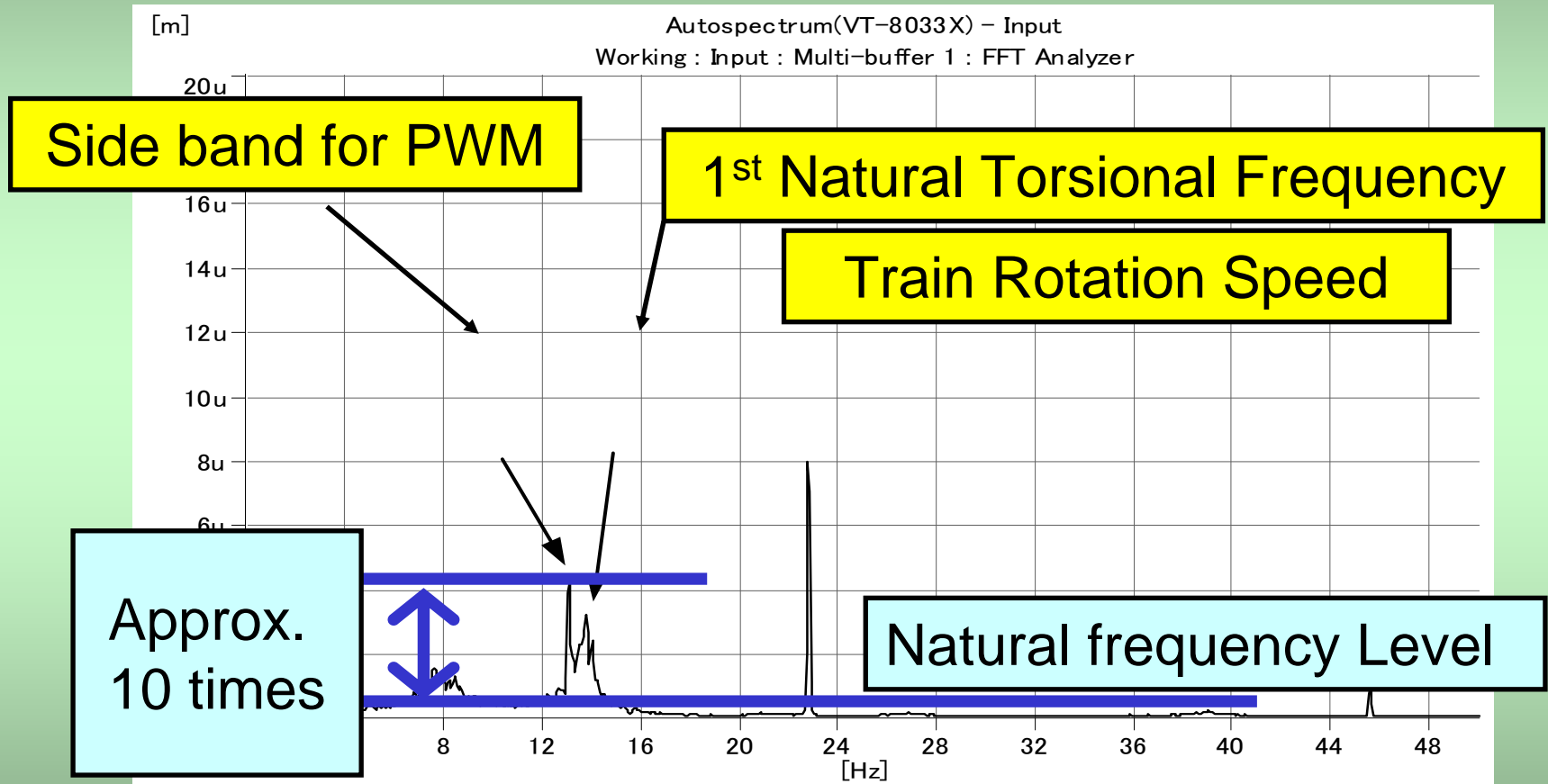
Problem



This coupling was broken!,
after **2,000 hr** of operational time.

Service	Fuel Gas Comp. Train
Train Operating Speed	4,794 – 7,192 rpm
Rated power	13.65 MW

Diagnostic of Problem



The resonance was caused by torsional & torque ripple

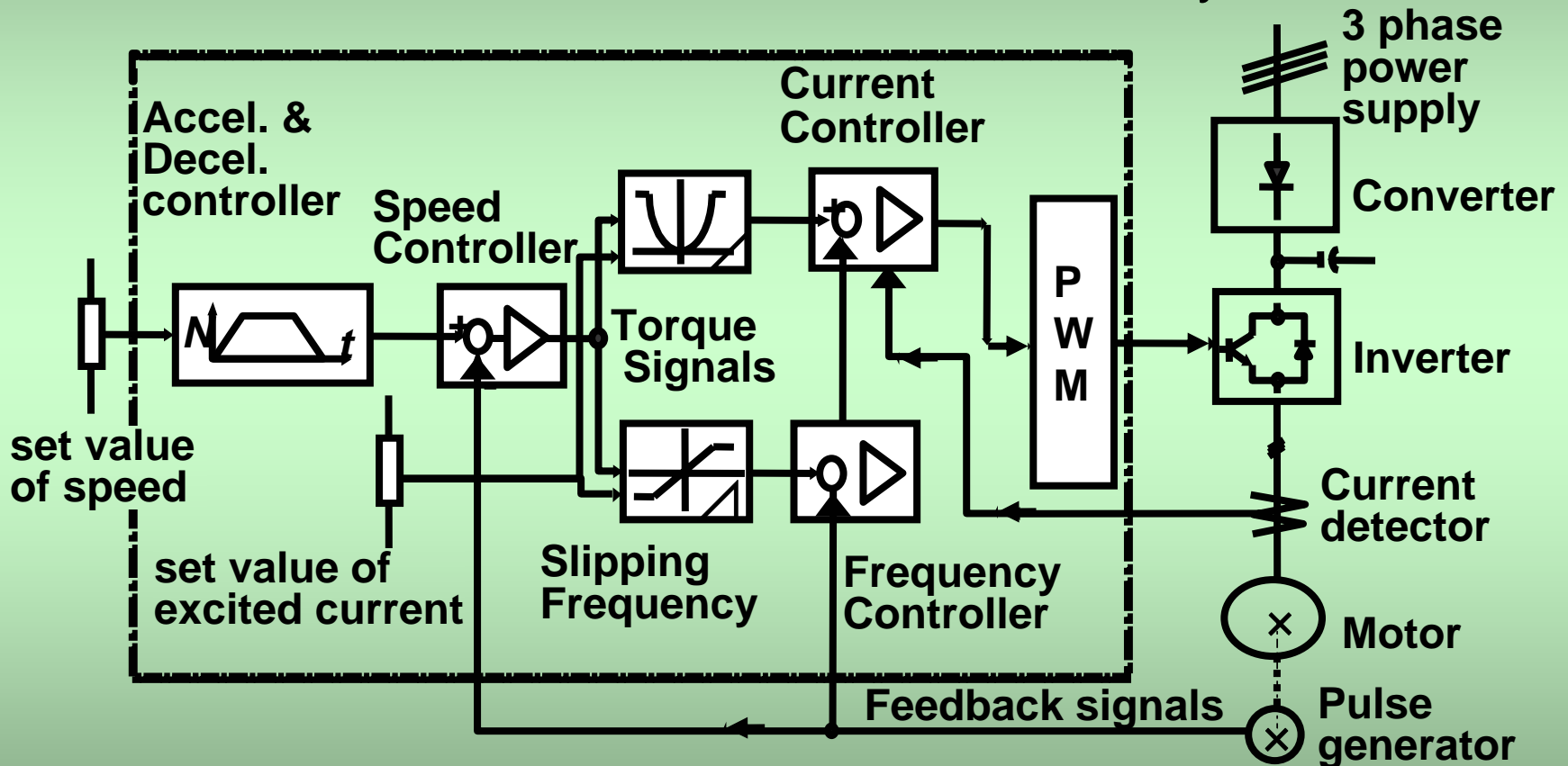
Specification of Motor equipment

ITEM	VALUE
Motor Type	Induction Motor
Line Frequency	50 Hz
Motor Voltage	3300 Vrms
Pole Number	4 Pole
Rated Power	13.65 MW
Motor Speed	1,050 – 1,575 rpm (35 - 52.5 Hz)
Gear Ratio	4.57
Train Operating Speed	4,794 – 7,192 rpm

Motor Speed Control Method

(Adjustable Voltage Adjustable Frequency with slip)

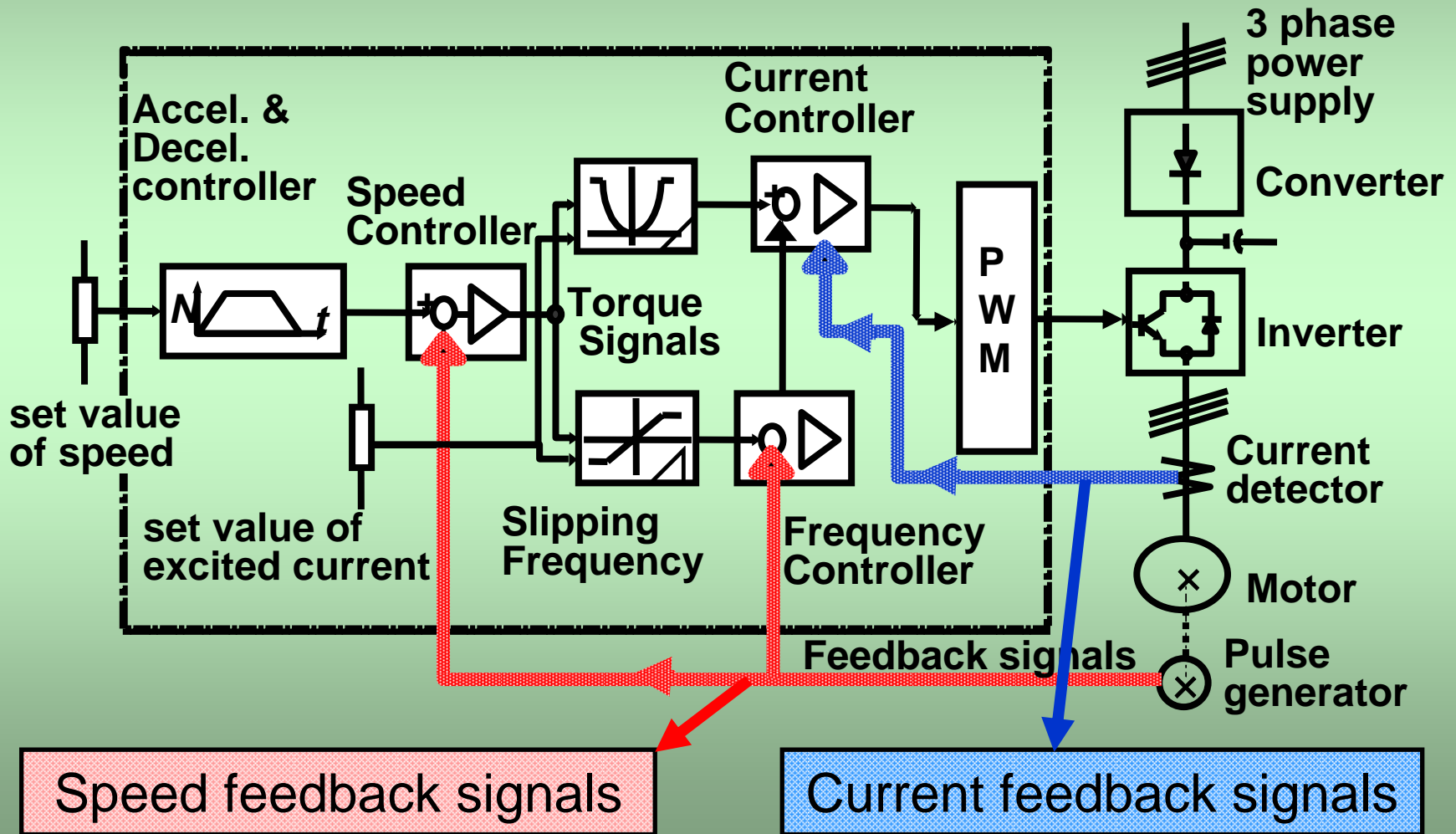
- extremely accurate -



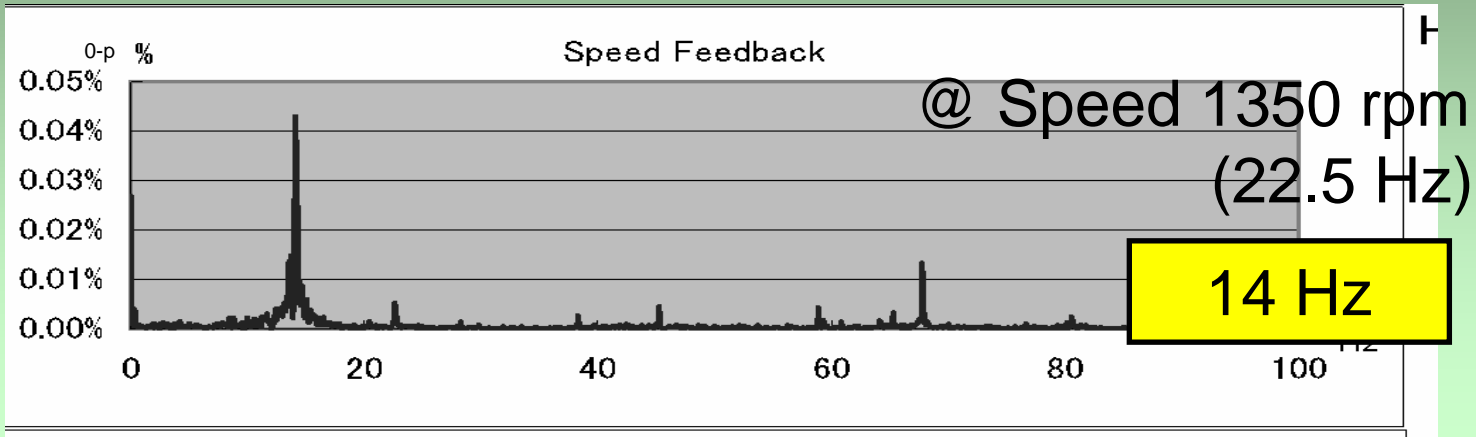
Within approx. 0.05 % of speed fluctuation rate for the difference between required & actual motor speed

Motor Speed Control Method

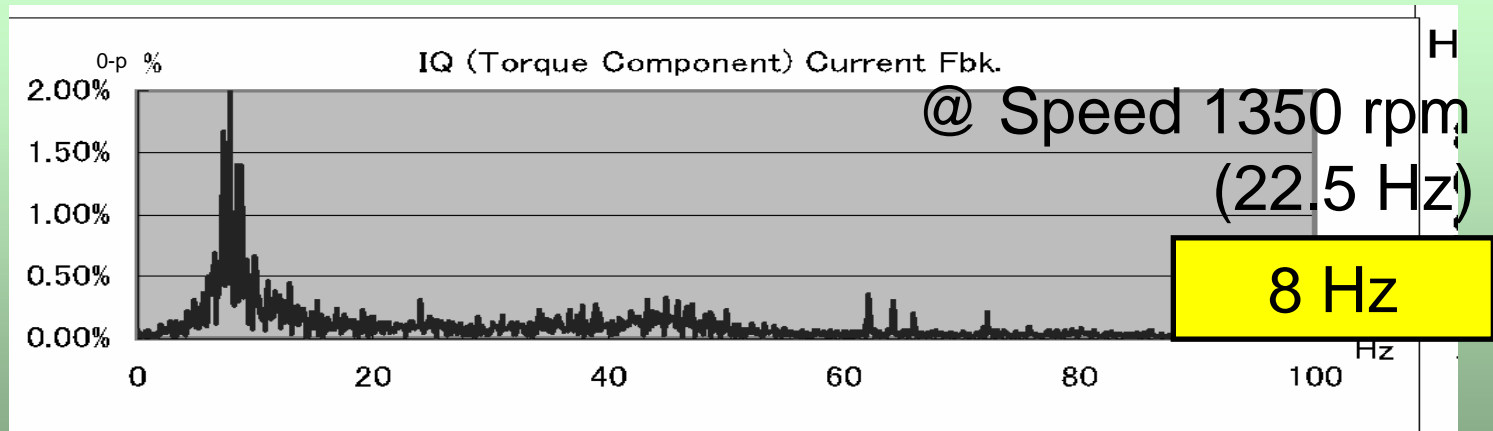
(Adjustable Voltage Adjustable Frequency with slip)



Site Measurement - FFT



Speed Feedback Signals (FFT)

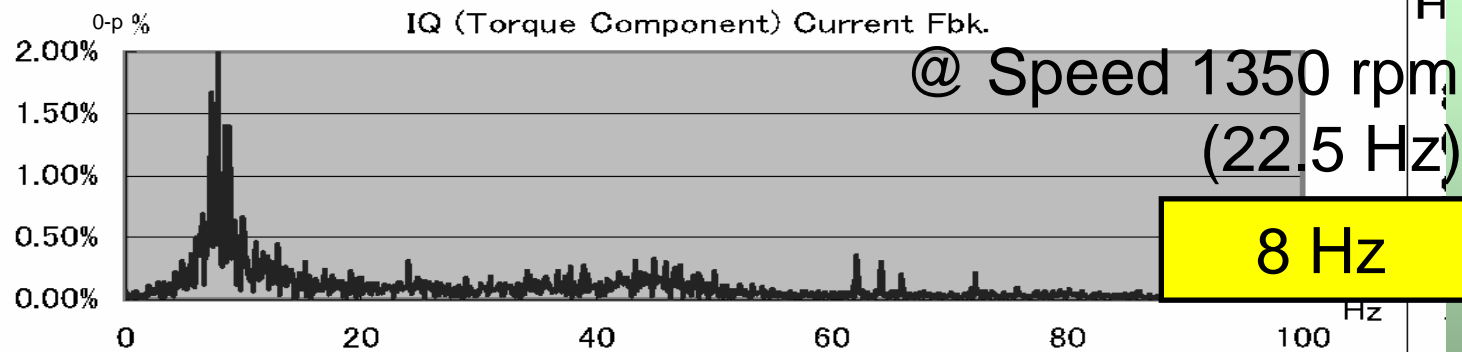


Motor Current Feedback Signals (FFT)

Site Measurement - FFT

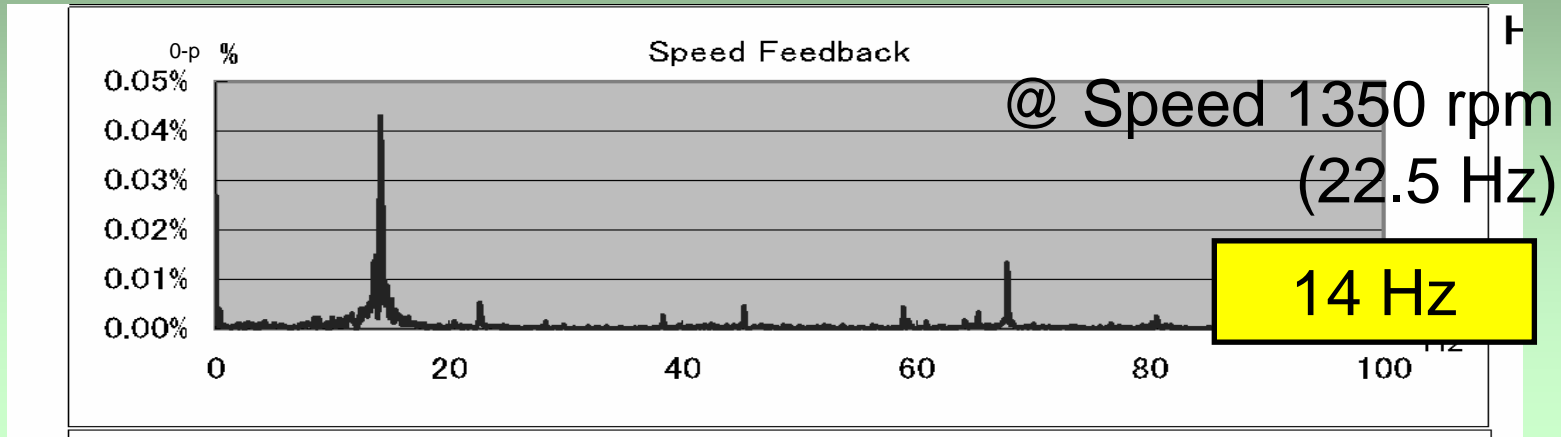
8 Hz was the poor adjustment of converter's gain.

Adjustment
at site



Motor Current Feedback Signals (FFT)

Site Measurement - FFT



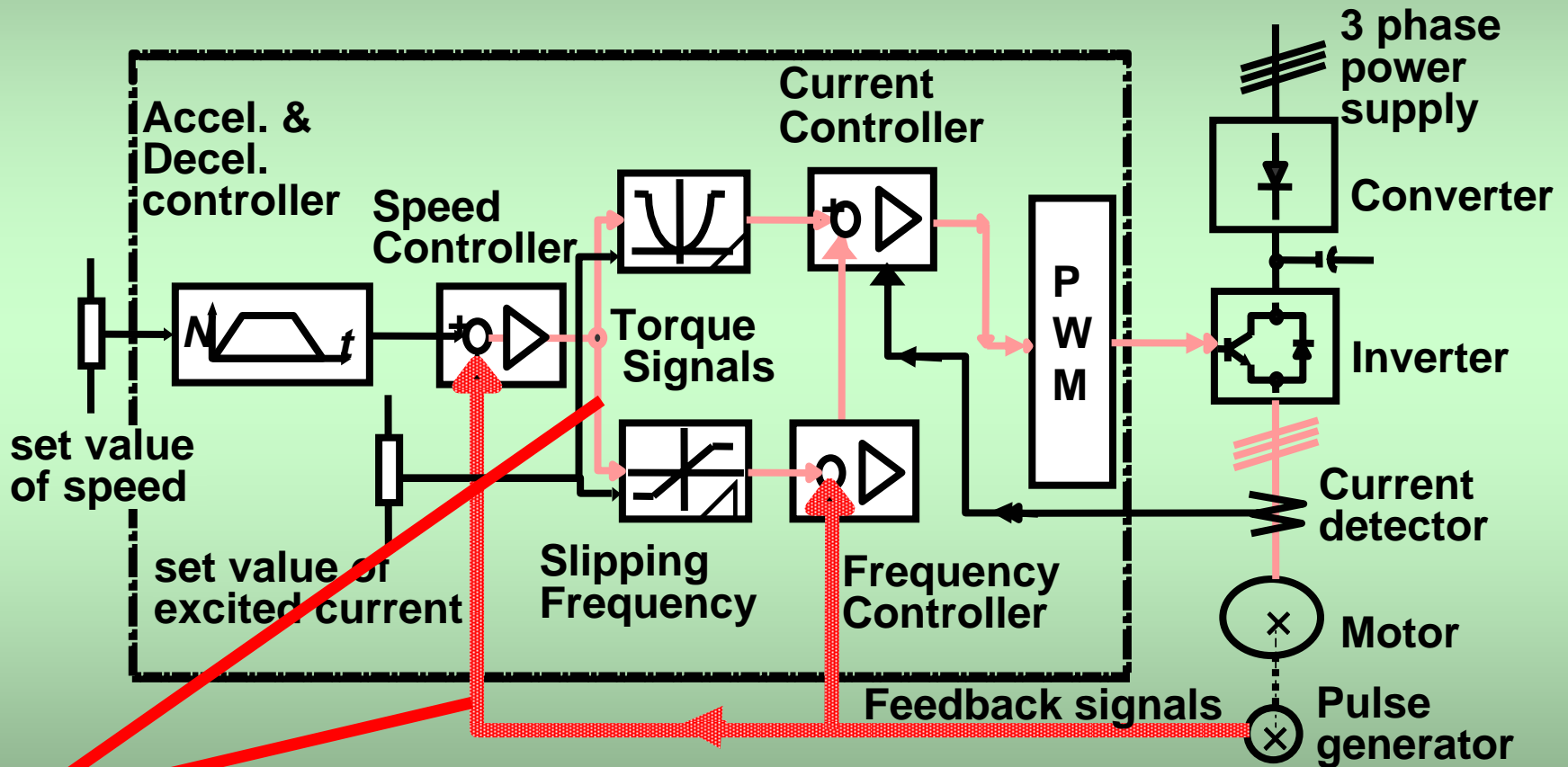
Speed Feedback Signals (FFT)

Frequency (Hz)	Speed Fluctuation Rate
14 Hz	0.043 % ^{0-P}
Overall	0.20 % ^{P-P}

Speed Fluctuation Rate

Study – Inverter (Assumption)

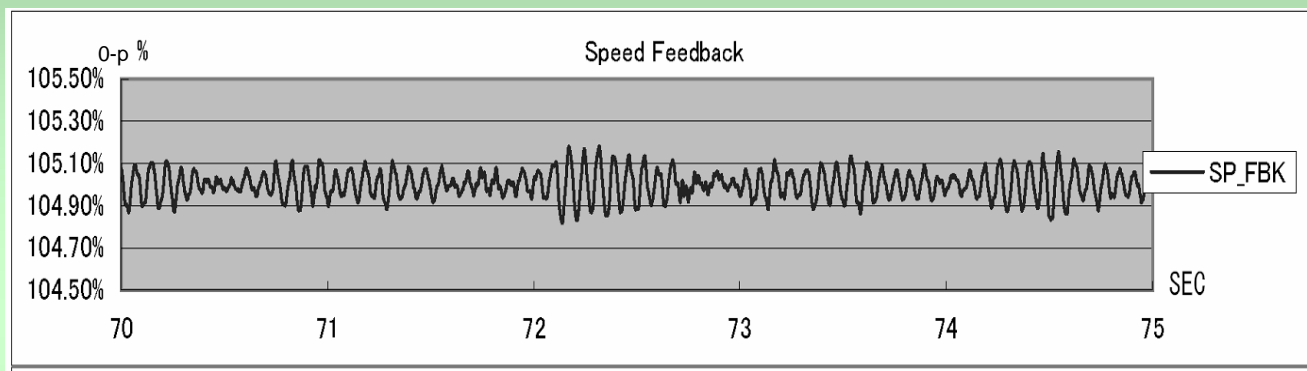
(Adjustable Voltage Adjustable Frequency with slip)



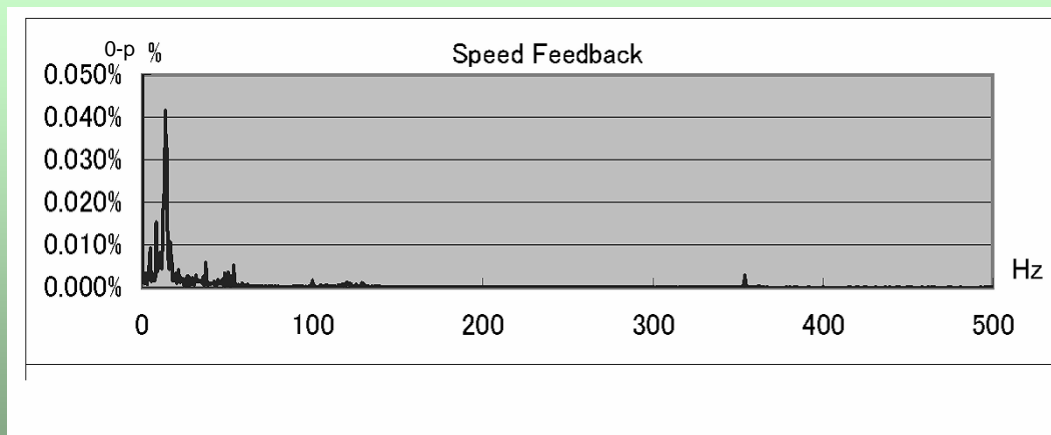
Our attention: closed loop circuit / Speed feedback signals

Study – Inverter (Simulation/Reappearance)

(Adjustable Voltage Adjustable Frequency with slip)



Speed feedback signals – Simulation -

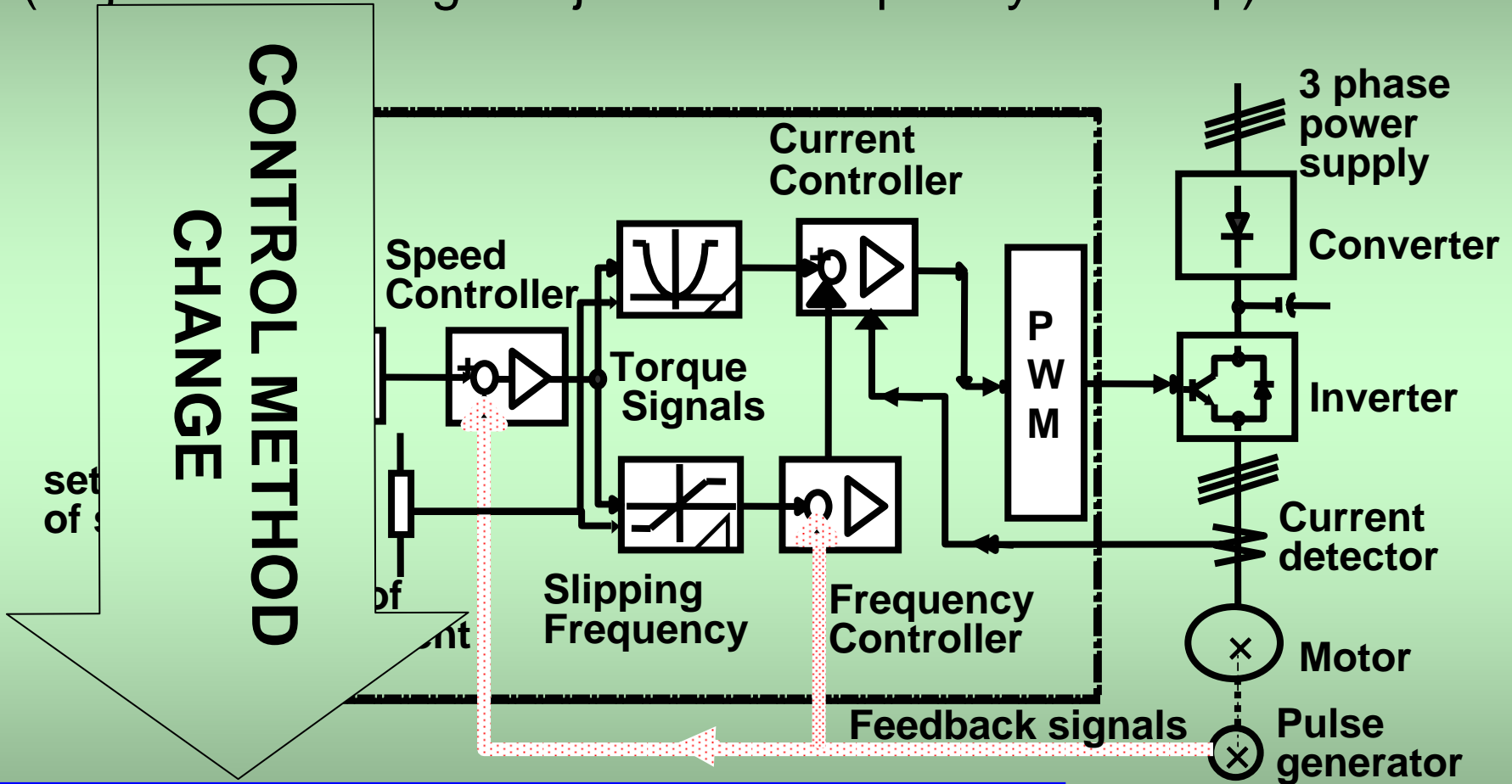


Speed feedback signals (FFT) – Simulation - 15

Study – Inverter

~~(countermeasures)~~

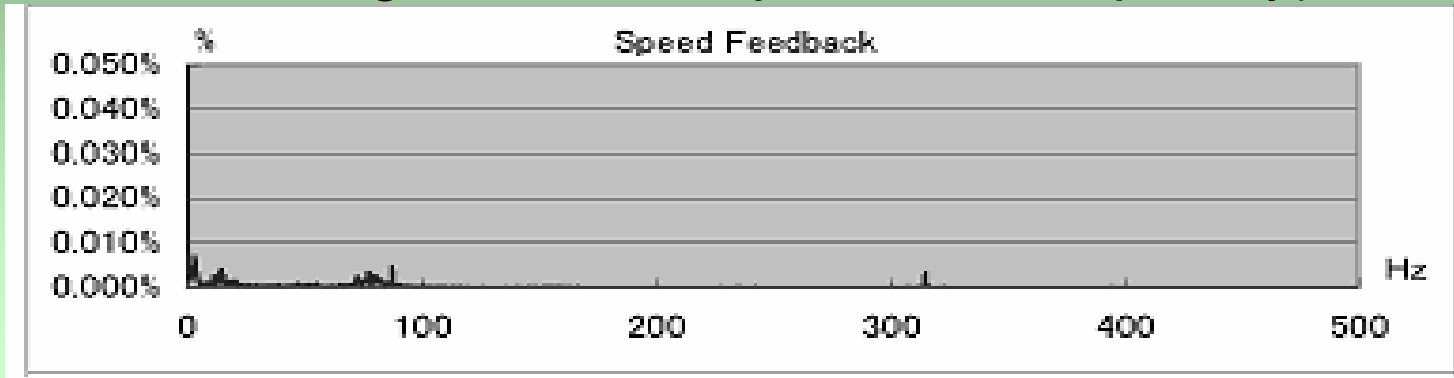
(Adjustable Voltage Adjustable Frequency with slip)



**V/F Control
(without speed feedback control)**

Study – Inverter (Modification)

(Adjustable Voltage without Adjustable Frequency)

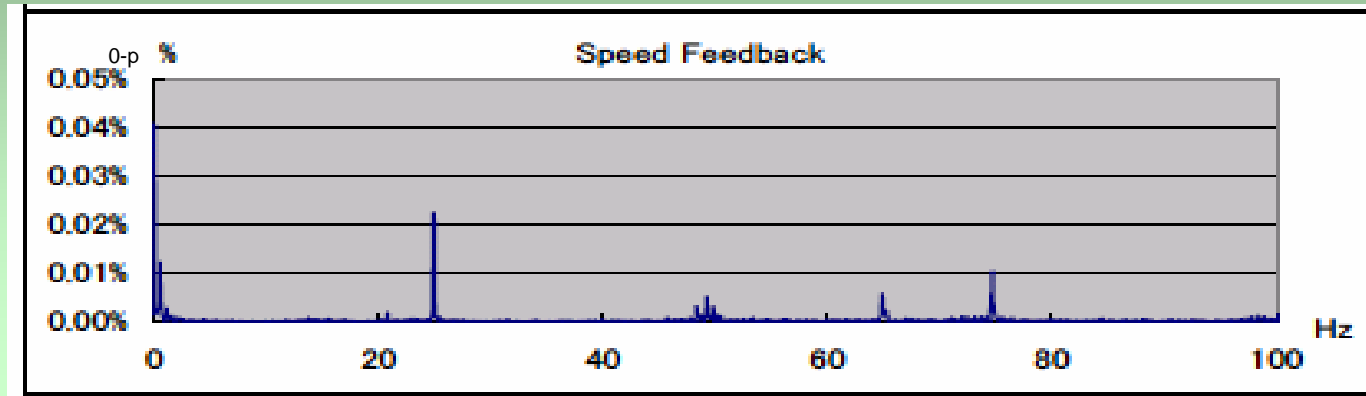


Speed feedback signals (FFT) – **Simulation** -

Frequency (Hz)	Original	Improved
14 Hz	0.0417 % ^{0-P}	0.0005 % ^{0-P}

For 14 Hz, Electrical-Mechanical resonance Frequency
Reduction Ratio : 2/100 (in simulation)
Speed feedback is a cause!

Site Measurement after Modification



Speed Feedback Signals (FFT)

**For 14 Hz, Electrical – Mechanical Resonance
Reduction ratio : 7 / 100 (actual data)**

Frequency	Original	Improved
(Hz) 14 Hz	0.043 % ^{0-P}	0.003 % ^{0-P}
Overall	0.20 % ^{P-P}	0.10 % ^{P-P}

Conclusion

- 1, The sensitivity of accurate speed and torque controls with Vector control & Converter phase control in a compressor train without damping, involves risk.
- 2, This study has verified that the V/F control for the synchronized PWM inverter efficiently controls the motor used in a compressor train in which load fluctuates very slowly with small damping.
- 3, In conclusion, by recognizing the importance of torque ripple on the motor side during the designing stage, a motor driven compressor train can be successfully stabilized with V/F control, without speed feedback.