# **MATLAB EXPO 2021**

진동 데이터 기반 배터리 커터 고장진단 딥러닝 모델 개발 *이정훈, LG에너지솔루션* 



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🕞 LG에너지솔루션

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# LG에너지솔루션 Mobility & IT

#### Mobility & IT Battery Solutions



#### **LG에너지솔루션** Advanced Automotive



# **LG에너지솔루션** Energy Storage System

![](_page_6_Figure_2.jpeg)

# **LG에너지솔루션** Global Operations

![](_page_7_Figure_2.jpeg)

# 프로젝트 개요

#### Objective

 Development of Vibration Data-Driven Model for <u>Battery Electrode Cutter Fault Diagnosis</u> <u>System</u> using MATLAB Deep Learning Workflow

#### Milestones & Members

- Total 6 months (Sep. 2020 ~ Mar. 2021)
- Junghoon Lee (LG Energy Solution) / Wanbin Song, Kevin Suh, Jake Kim (MathWorks)

#### Conclusion

- Interactively analyzed raw field data by applying various MathWorks Apps, including Signal Analyzer and Diagnostic Feature Designer
- Established <u>reusable machine learning development workflow</u> with rich discussion of domain knowledge from LG Energy Solution and feature engineering and machine learning techniques from MathWorks
- <u>Tested a prototype of Battery Electrode Cutter Fault Diagnosis System</u> at a pilot line of LG Energy Solution

# 기술적인 해결과제

#### Background

 Currently maintenance of battery electrode cutter is scheduled periodically and rely on site operator's opinion

![](_page_9_Picture_4.jpeg)

# 기술적인 해결과제

#### Solution Concept

 Monitoring vibration generated during electrode cutting to diagnose cutter life and predict replacement timing in advance

![](_page_10_Figure_4.jpeg)

### MathWorks 솔루션을 통한 해결 방안 및 결과 Machine Learning Development Workflow

Focused on algorithm development part

![](_page_11_Figure_3.jpeg)

# MathWorks 솔루션을 통한 해결 방안 및 결과

Key takeaways of each stage

• Explore and preprocess data

- 3 channel data for each observation
- Explore and analyze signal with respect to time-domain and spectraldomain using Signal Analyzer App
- Provide possibilities on how to gain insight from signal data.

![](_page_12_Figure_7.jpeg)

![](_page_12_Picture_8.jpeg)

Discover patterns

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# MathWorks 솔루션을 통한 해결 방안 및 결과

Key takeaways of each stage

- Feature Engineering

![](_page_13_Figure_4.jpeg)

![](_page_13_Picture_5.jpeg)

<Auto-generated Feature designing function>

- Feature extraction using Diagnostic Feature Designer and analyze discernment of normal data from abnormal
- Figure out that some of features can distinguish normal/abnormal data
- Provide possibilities on feature ranking, transformation and merging.

Domain Knowledge Select Features

# MathWorks 솔루션을 통한 해결 방안 및 결과 Key takeaways of each stage

Machine / Deep Learning for Anomaly detection 

0.2%

0.1%

Confusion Matrix: Validation Da Before 621 클래스 After 99.9% 99.9% 0.2% 0.1% Before After 예측 클래스

<Machine Learning model>

- Supervised Learning
  - Classification model trained and optimized with learner app
- Unsupervised Learning
  - PCA and Kmeans clustering
  - AutoEncoder for anomaly detection
- More steady state dataset can improve the trained model.

![](_page_14_Figure_11.jpeg)

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• Step Training • Cancel • Auto-encoder trainnig >	Method	Validation Accuracy
р	2 class classification	99.86 %
	5 class classification	92.51 %
	PCA	N/A
	K-means Clustering	85.39 %
ned model	Auto Encoder	97.33 %

![](_page_14_Picture_13.jpeg)

![](_page_14_Picture_14.jpeg)

![](_page_14_Picture_15.jpeg)

<Dimension reduction>

# 결과 및 정리

 Machine / Deep Learning analysis of data before and after Lamination Cutter replacement results in 95% chance to diagnose Cutter health

![](_page_15_Figure_3.jpeg)

# 다음 과제

- Data acquisition and modeling cutter vibration data by battery model
- <u>Real-time Battery Electrode Cutter Fault Diagnosis System</u> set-up and verification by checking vibration data generated when cutting battery electrodes

![](_page_16_Figure_4.jpeg)

 Deployment after completing pilot line verification using an app designbased compiled program

# 결론

#### Conclusion Summary

- LG Energy Solution and MathWorks successfully completed the cooperation including technical guidance with LG Energy Soultion's raw field data
- LG Energy Solution and MathWorks <u>developed a condition monitoring system</u> to avoid wasteful maintenance as well as unexpected failures
- After training the anomaly detection model with selected features from a raw dataset, We successfully integrated the model into the production line
- LG Energy Solution established <u>reusable Machine / Deep Learning development workflow</u> with rich discussion of domain knowledge from LG Energy Solution and feature engineering and machine learning techniques from MathWorks

#### Advantages of using MATLAB and Simulink

- Interactive Apps for generating features and training various models
- Capabilities of entire workflow from data acquisition to deployment
- Leveraged MathWorks engineer's support for fast prototyping