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Signal Generation using 1d Deep Convolutional Generative Adversarial Networks for Fault Diagnosis of Electrical Machines

By

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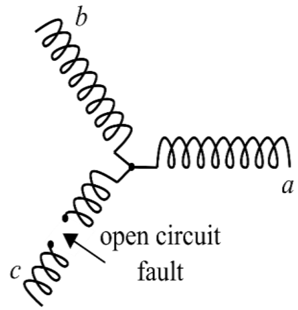
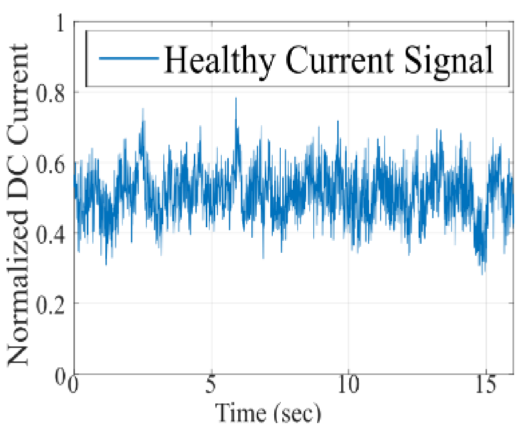
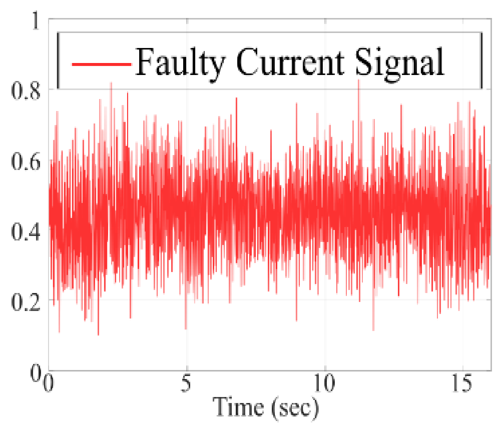
Motivation

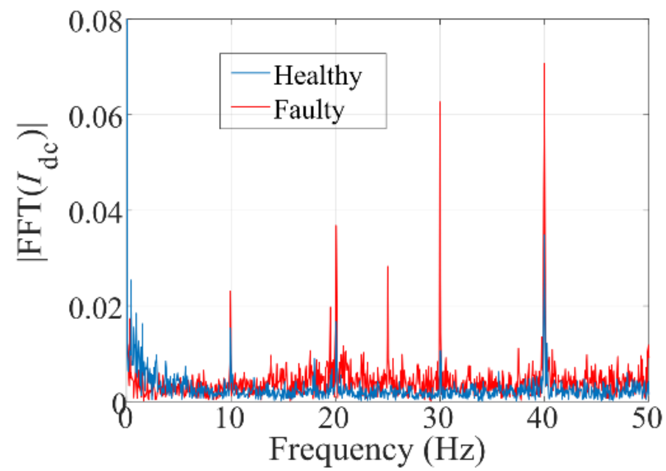
SIGNAL GENERATION USING 1D DEEP CONVOLUTIONAL GENERATIVE ADVERSARIAL NETWORKS FOR FAULT DIAGNOSIS OF ELECTRICAL MACHINES

▶ Synchronous Machines Faults









Data generation using GAN

Problem Statement

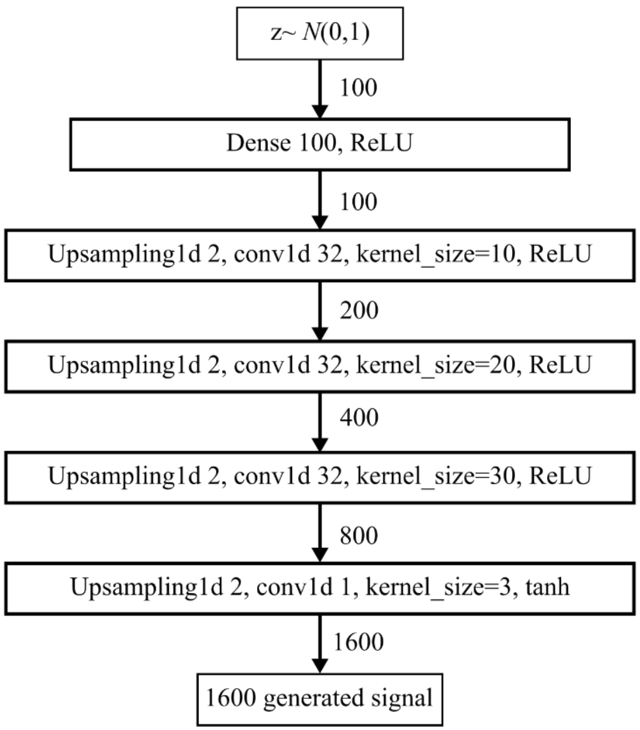
- 1-D convolution neural network with Wavelet Packet Transform **98.8% accuracy**
  (I. Kao, W. Wang, Y. Lai and J. Perng, "Analysis of Permanent Magnet Synchronous Motor Fault Diagnosis Based on Learning," in IEEE Transactions on Instrumentation and Measurement)
- Stacked Autoencoder with softmax layer **96.4% accuracy**
  (I. Kao, W. Wang, I. Chiang and J. Perng, "Implementation of Permanent Magnet Synchronous Motor Fault Diagnosis by a Stacked Autoencoder," 2018 IEEE International Conference on Consumer Electronics-Taiwan (ICCE-TW))

- Challenges with Deep Learning Algorithms
  - Deep Learning methods require large amounts of data
  - Algorithms don't generalize with large data

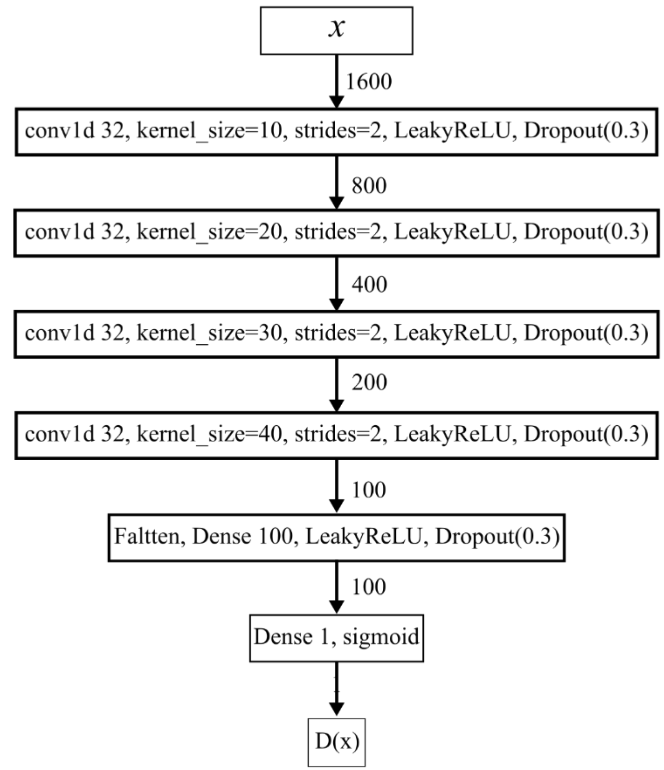
GAN Architecture

SIGNAL GENERATION USING 1D DEEP CONVOLUTIONAL GENERATIVE ADVERSARIAL NETWORKS FOR FAULT DIAGNOSIS OF ELECTRICAL MACHINES

Generator



Discriminator

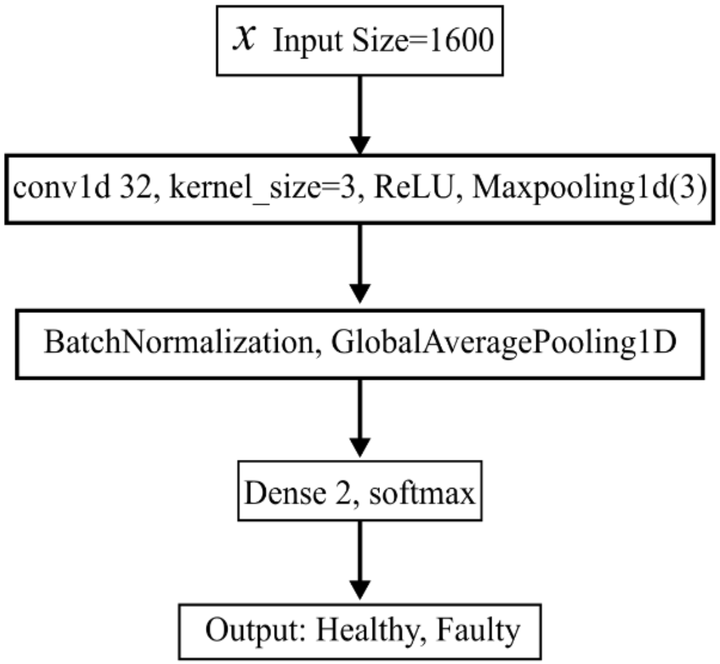


Evaluation of GAN using FID

- Fréchet Inception Distance (FID)

$$FID = \|\mu_1 - \mu_2\|^2 + Tr\left(C_1 + C_2 - 2(C_1 C_2)^{1/2}\right)$$

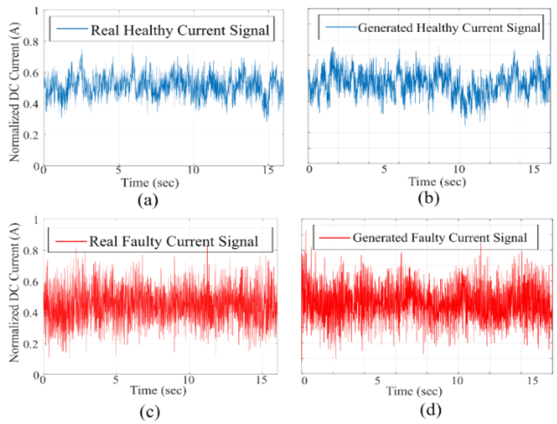
where, μ_1 and μ_2 are the feature wise mean
C_1 and C_2 are the covariance matrices
And Tr is the trace of the matrix

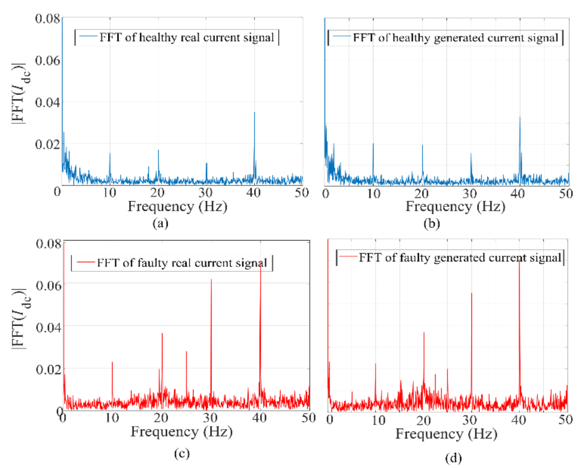


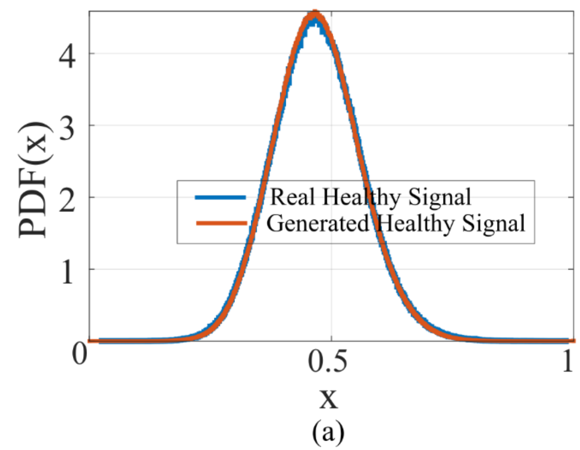
- Threshold: 5 x 1E-5

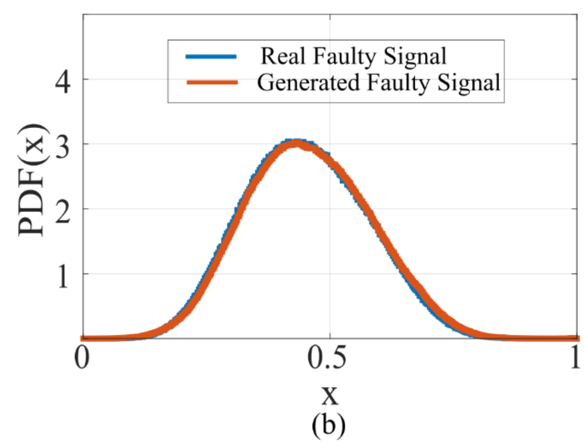
Generated Data Results

SIGNAL GENERATION USING 1D DEEP CONVOLUTIONAL GENERATIVE ADVERSARIAL NETWORKS FOR FAULT DIAGNOSIS OF ELECTRICAL MACHINES









Further evaluation of GAN

- **Creativity:** The generated signals are not duplicates of the real signals.
- **Diversity:** The generated signals are not duplicates of each other.

$$SSIM(x,y) = \frac{(2\mu_x\mu_y+c_1)(2\sigma_{xy}+c_2)}{(\mu_x^2+\mu_y^2+c_1)(\sigma_x^2+\sigma_y^2+c_2)}$$

μ_x is the mean value of x
μ_y is the mean value of y
σ_x^2 is the variance of x
σ_y^2 is the variance of y
σ_{xy} is the covariance of x and y
$c_1 = (k_1 L)^2$ and $c_2 = (k_2 L)^2$ are the variables to stabilize to the division with weak denominator
In our case $k_1 = k_2 = 0.05$, and L is the dynamic range of the signal value

$$Creativity = \frac{Number\ of\ Nonduplicate\ Signal}{Number\ of\ Signals\ in\ the\ generated\ dataset}$$

$$Diversity = -\sum_{i=1}^{m} p_i \log p_i$$

where, $p_i = |C_i| / \sum_{n=1}^{m} |C_n|$
m is the number of clusters
$|C_i|$ is the number of signals in the cluster where $i = 1, \ldots\ldots m$

Conclusion

	1d DCGAN trained on Healthy signals	1d DCGAN trained on Faulty signals	Optimal values for 10000 signal dataset
Creativity	1	1	1
Diversity	9.0	8.7	9.2

- 1d signals generation using DCGAN
- Evaluation using FID distance
- Further evaluation using Creativity and Diversity
- Generated Signals are statically rich and are uncorrelated to the real signals

THANK YOU