PSG INSTITUTE OF TECHNOLOGY AND APPLIED RESEARCH

Neelambur, Coimbatore – 641 062

Smart Drainage, Effluent and Sewage Pumping System

TEAM:
PSG iTech – 2
CATEGORY:
Smart Machines

Team Details

Participant Name	CT /DT Number	Role (Team Leader / Member)	Bachelors Discipline	Expected Year of Passing	Gender
Shravan S	CT20182402848	Team Leader	Electrical and Electronics Engineering	2020	M
Raagul A S	CT20182408578	Team Member	Mechanical Engineering	2020	M
Anirudh P S	CT20182401507	Team Member	Electronics and Communication Engineering	2020	M
Ramprakash V	CT20182408971	Team Member	Computer Science Engineering	2020	M

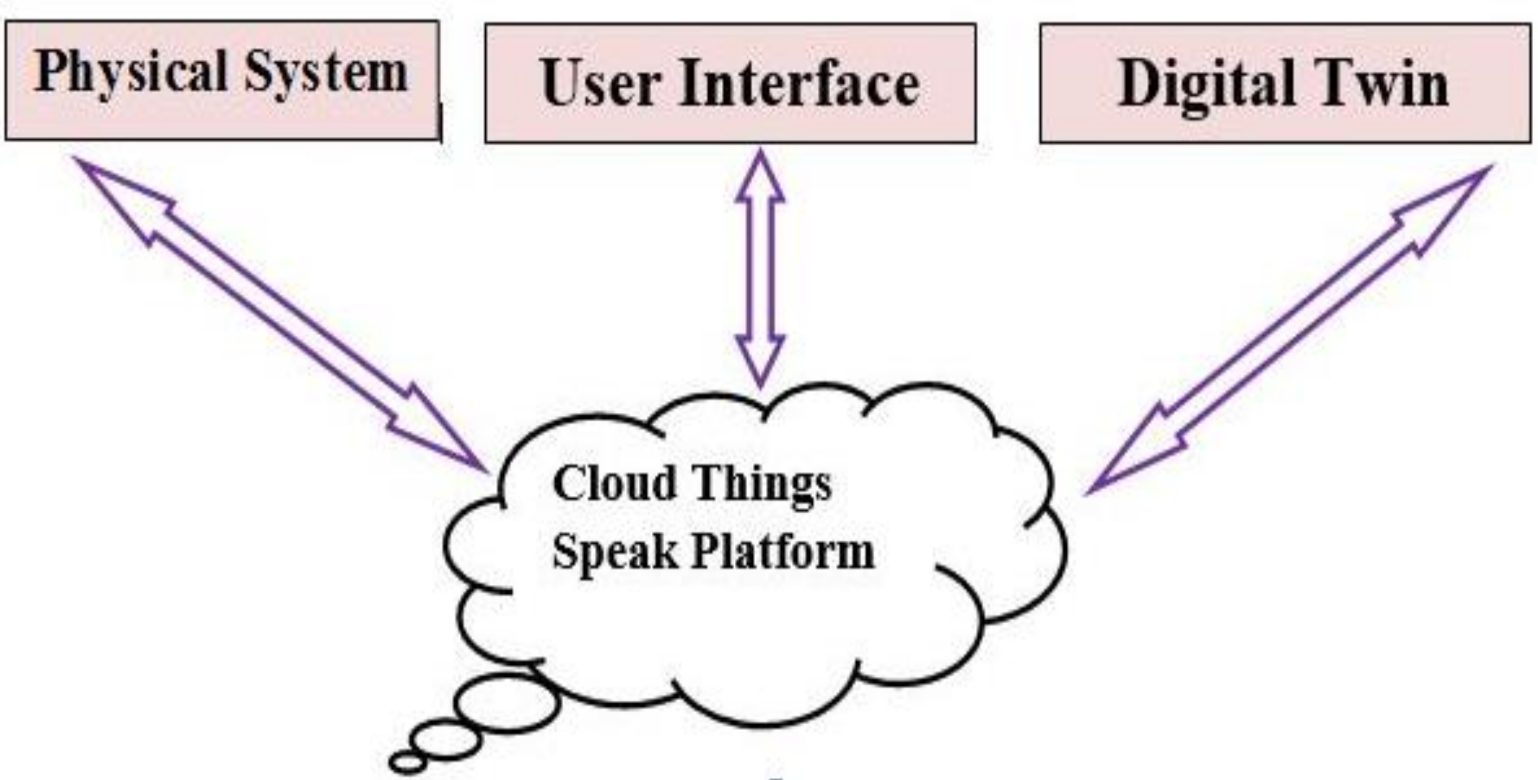
Objective Of Proposed Solution

- **Pumping of drainage, effluent and sewage is different from pumping of water due to the polluted nature of the materials.**
- **The pollutants are in the form of suspended solids and floating solids. Hence, the load on the pump varies widely.**
- **The proposed system will monitor single phasing fault, stator temperature, vibration, and ambient temperature, and will dynamically control the speed of the pump and ensure sustained reliable performance of the pump.**

Objective Of Proposed Solution

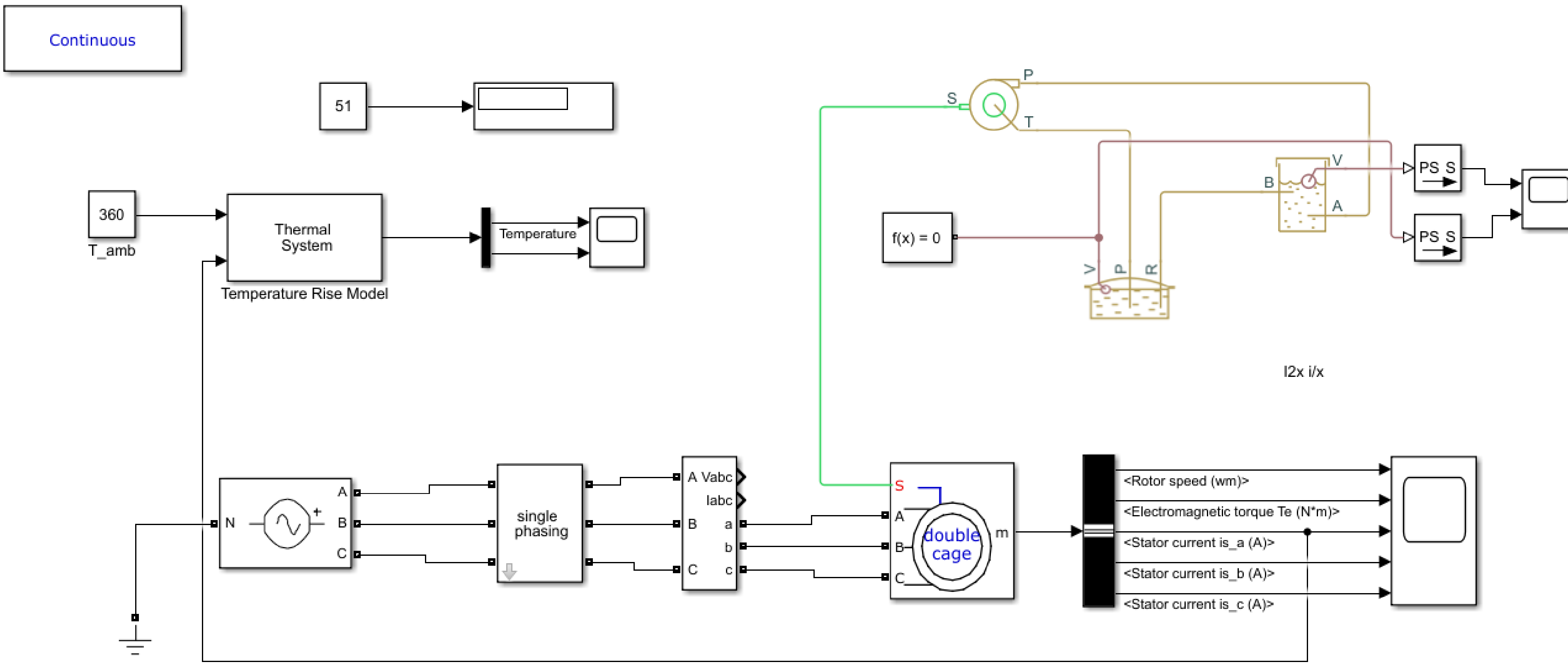
- **Intelligence, by way of machine learning, is built into the system using mathematical expressions that characterize the physical system, and data analytics.**
- **The users can query the digital twin to know the historical performance, and current operating conditions.**
- **The proposed system can trigger alarms as early warnings, and also make predictions about possible system anomalies, if and when they occur**

System Architecture



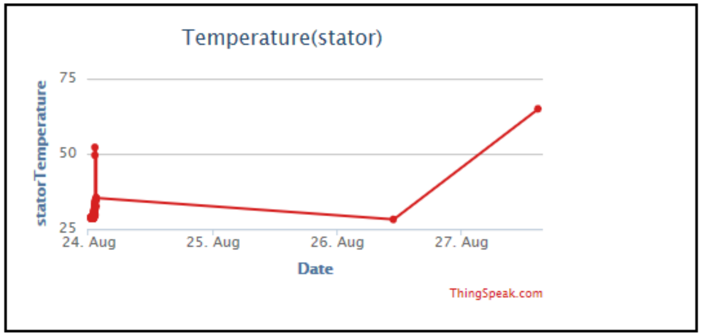
Physical System

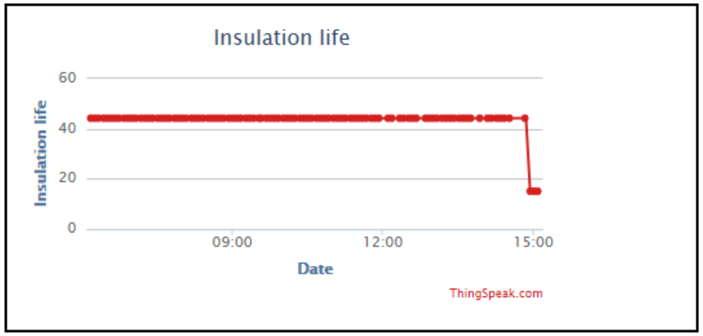
Digital Twin

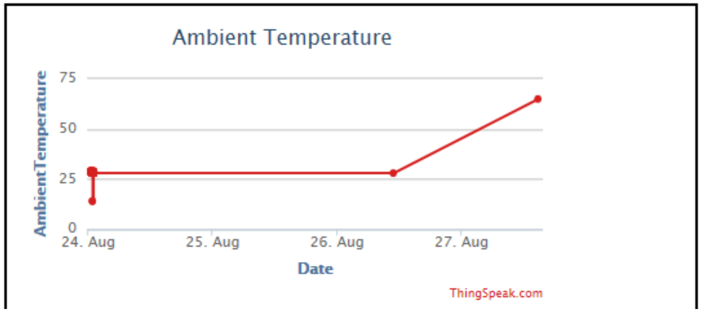


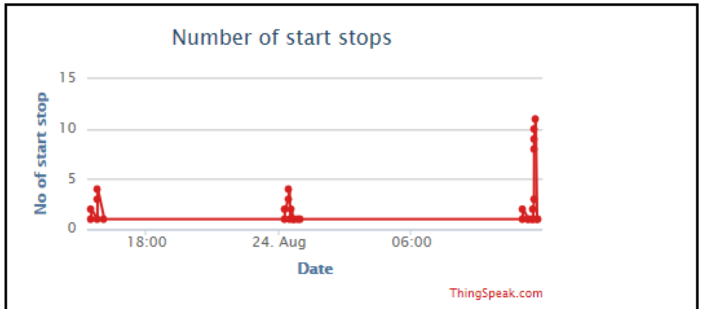
Cloud and User Interfacing

SMART DRAINAGE EFFLUENT AND SEWAGE PUMPING SYSTEM





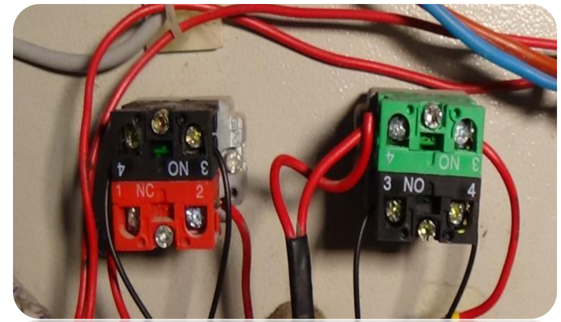




SYSTEM OPERATION

Starting The Digital Twin

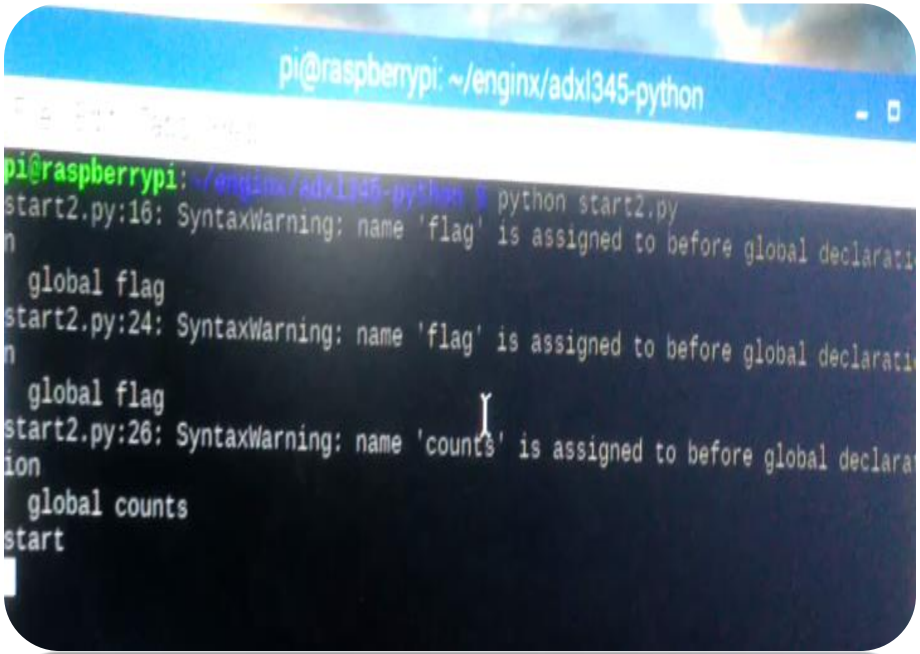
Start push button is pressed

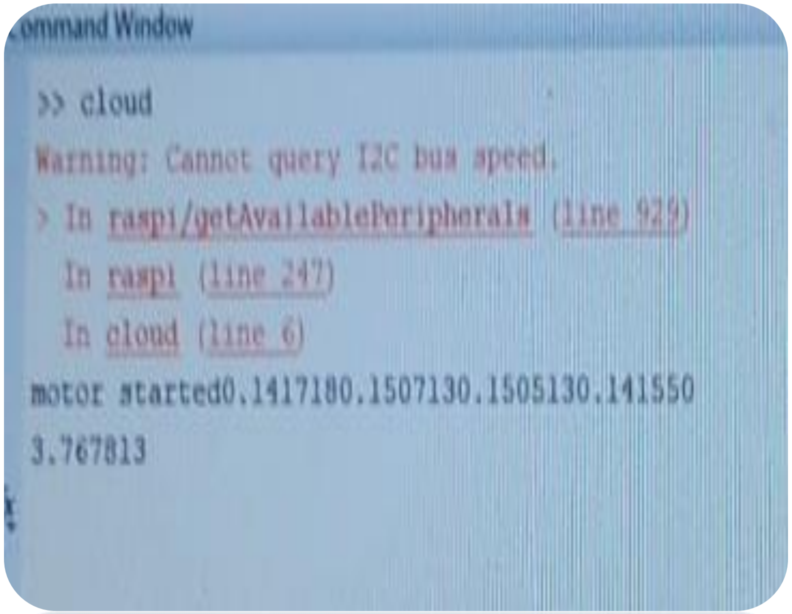


Auxiliary contactors gets actuated

MATLAB

Starting The Digital Twin



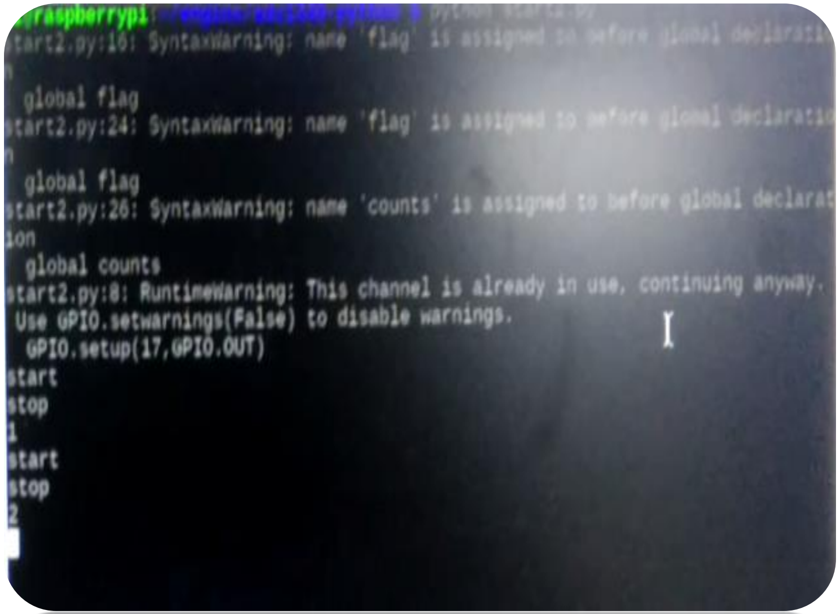


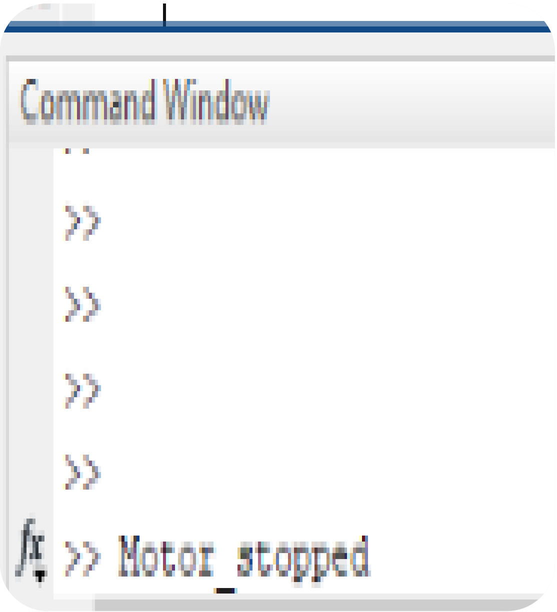
Stopping The Digital Twin

Stop push button is pressed

Auxiliary contactors get actuated

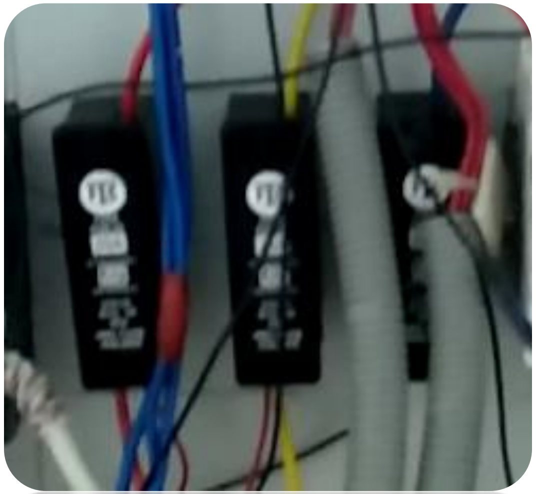
Stopping The Digital Twin





SINGLE PHASING FAULT

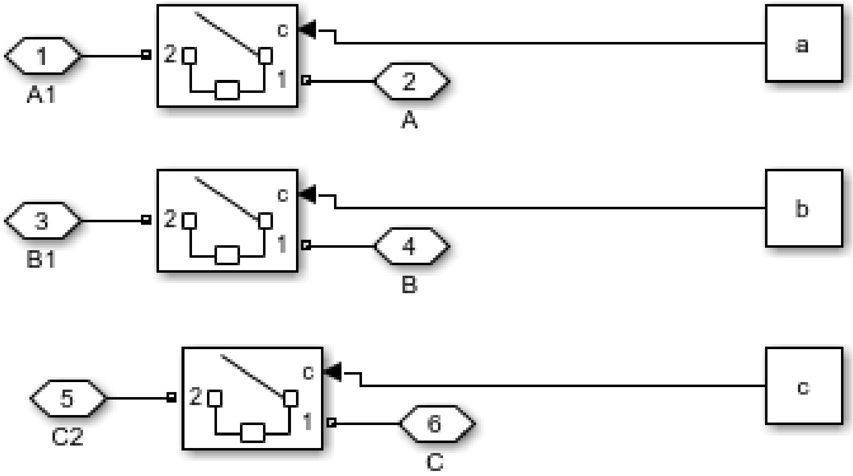
Single Phasing Fault



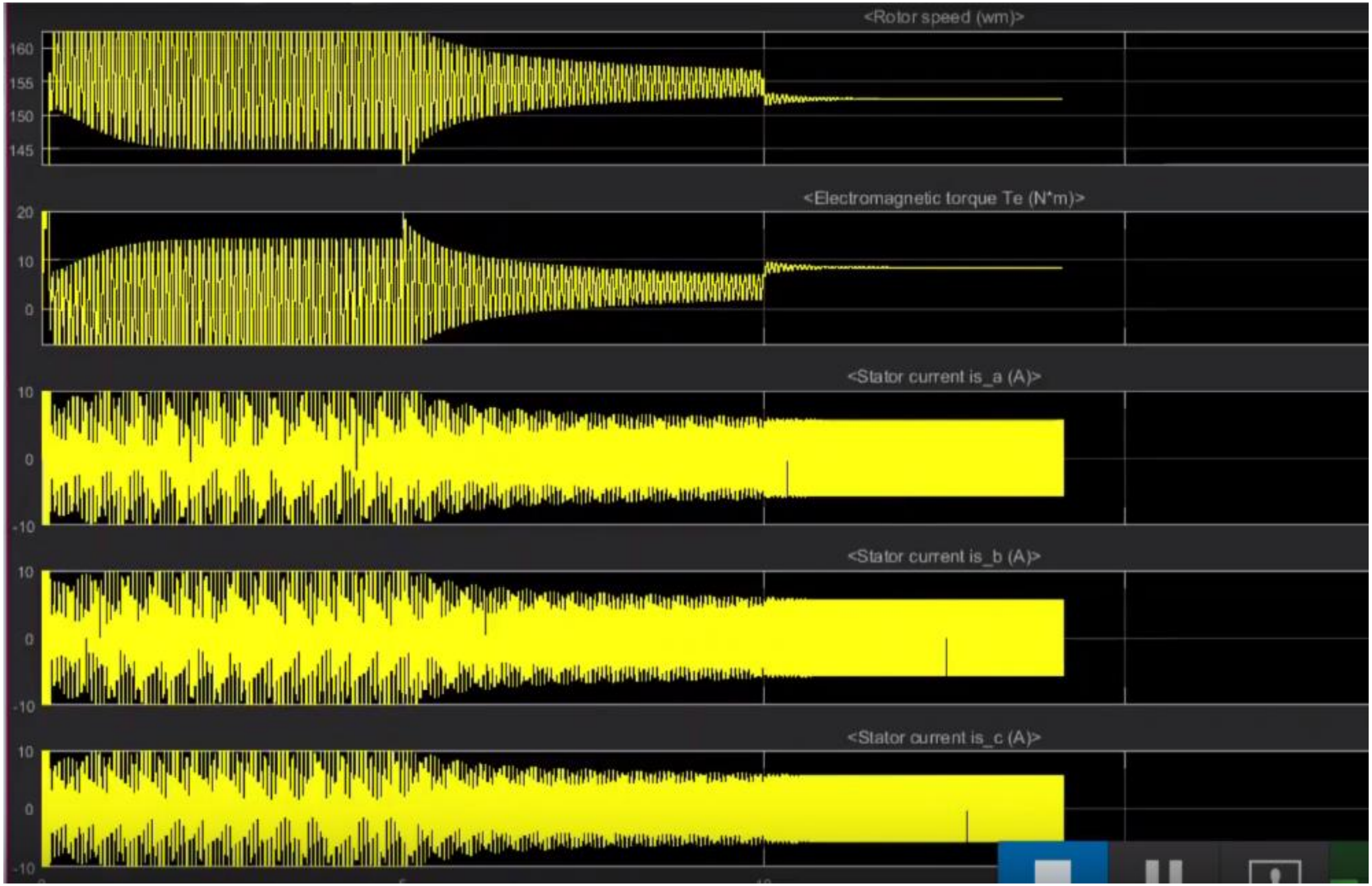
Electrical Fuse

Energy Meter

Single Phasing Fault-Twin



Electrical Parameters Waveform



Single Phasing Fault-Waveform

THERMAL SUBSYSTEM

Insulation Life Estimation

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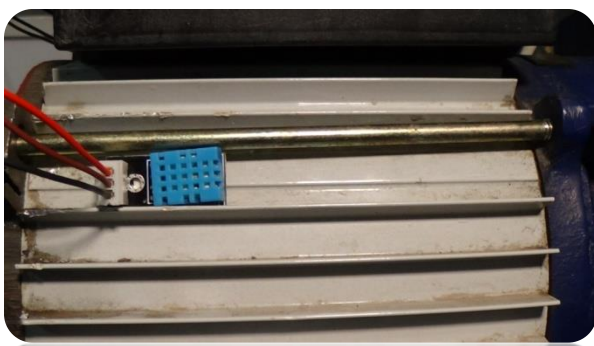
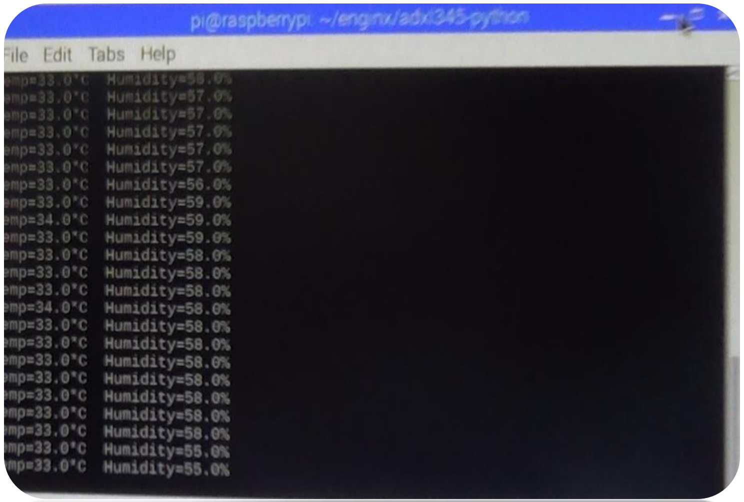
Load current data from Energy Meter



Ambient Temperature from DHT 11

Insulation Life Estimation



Ambient Temperature readings in Raspberry Pi Screen

Ambient Temperature Readings Being Plotted In ThingSpeak

Insulation Life Estimation

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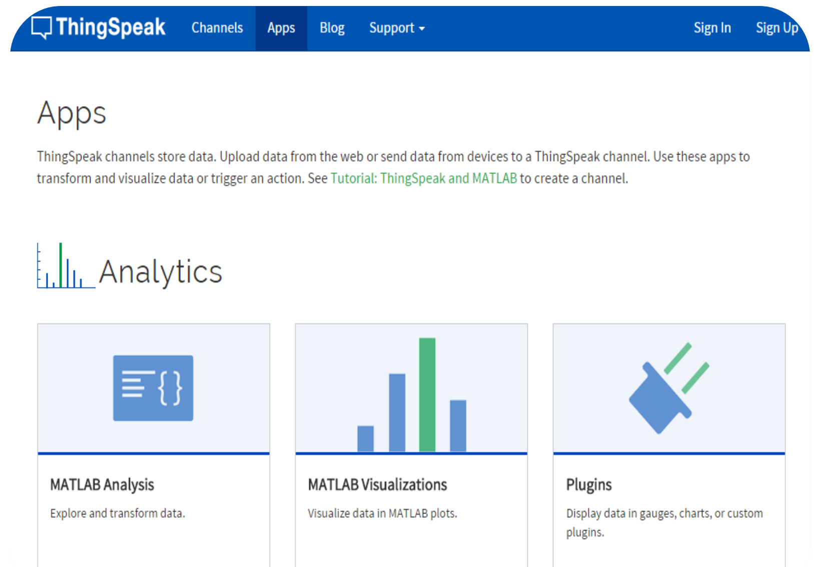
Ambient Temperature Readings Being Plotted In ThingSpeak

MATLAB

Load Current Data From MATLAB



Insulation Lifetime Estimation Using MATLAB Analytics in ThingSpeak platform

Algorithms Behind Insulation Life Estimation:

- Montsinger Rule
- Arrhenius Equation
- **Final consolidated equations:**

1. Hotspot Temperature =[Loss Factor*Allowable temperature rise]+Ambient Temperature

2. $$L_x = L_{100} * 2\exp\left[\frac{T_C - T_X}{HIC}\right]$$

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Code Snippets:

```
clc;
% Parameter Declarations
Class=[105 130 155 180];
HIC=[14 11 9.3 8];
Load_Factor=50:1:150;
[r c]=size(Load_Factor);
Loss_Factor=zeros(1,c);
for i=1:1:c
    Loss_Factor(i)=0.012*Load_Factor(i)*Load_Factor(i)-(0.83*Load_Factor(i))+65;
end
Loss_Factor;
%%
Channel_ID=559226;
Channel_ID2=562478;
[Torque,timestamp]=thingSpeakRead(Channel_ID,'Fields',1,'NumPoints',10)
[rr cc]=size(Torque);
Torque_Tot=0;
count=0;
for i=1:1:rr
    temp=Torque(i);
    if isnan(temp)==0
        Torque_Tot=Torque_Tot+temp;
        count=count+1;
    end
end
Torque_Tot=Torque_Tot;
Temp_amb=thingSpeakRead(Channel_ID2,'ReadKey','PBLRW9SSRWYQI66Z','Fields',1);
Time_Period=20; % Current Load Duty time
```

Time_Period=20; % Current Load Duty time

```
Base_Load_Time=24;
LV_PU = Time_Period/Base_Load_Time;
Load_Tot= ceil(sum(Torque_Tot)/(LV_PU+count-1))
% Getting Class Insulation
%Ins_Class_Cell=thingSpeakRead(Channel_ID,'Fields',3,'OutputFormat','table');
%Ins_Class=Ins_Class_Cell.InsulationClass{1};
Ins_Class='B';

if Ins_Class=='A'
c=Class(1);
h=HIC(1);
end
if Ins_Class=='B'
c=Class(2);
h=HIC(2);
end
if Ins_Class=='F'
c=Class(3);
h=HIC(3);
end
if Ins_Class=='H'
c=Class(4);
h=HIC(4);
end
Inter_Load=Load_Factor-Load_Tot;
z=find(Inter_Load==0)
F=Loss_Factor(z)/100;
fprintf('Loss Factor F: %f\n',F);
T_hot=F*(c-Temp_amb)+Temp_amb;
fprintf('Hot spot Tx: %f\n',T_hot);
Lx=100*(2^((c-T_hot)/h));
E_year=((Lx*20000)/(100*24*365));
```

```
E_hours=E_year*24*365;
Elapsed=(LV_PU+count-1)*24;
E_year_rem=(E_hours-Elapsed)/(365*24);
fprintf('Expected life in year: %f \nDays: %f \nHours: %f\n',E_year_rem,E_year_rem*365,E_y
thingSpeakWrite(559243,E_year,'Fields',1,'WriteKey','SRHS7G3QM6EE7A0H');
if E_year*365 <100
    fprintf('Please Check for Insulation Replacement \n');
    thingSpeakWrite(563794,1,'WriteKey','T07N0YH6P6LL9WDB');
else
    thingSpeakWrite(563794,0,'WriteKey','T07N0YH6P6LL9WDB');
end
```

Insulation Life Estimation

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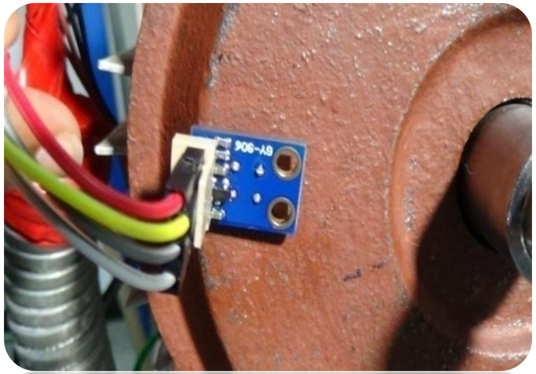
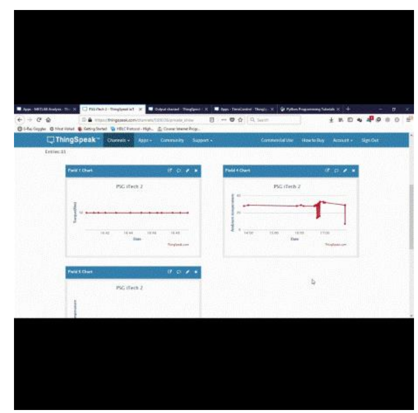
```
Loss Factor F: 0.542880
Hot spot Tx: 88.859200
Expected life in year: 30.493791
Days: 11130.233571
Hours: 267125.605715
```

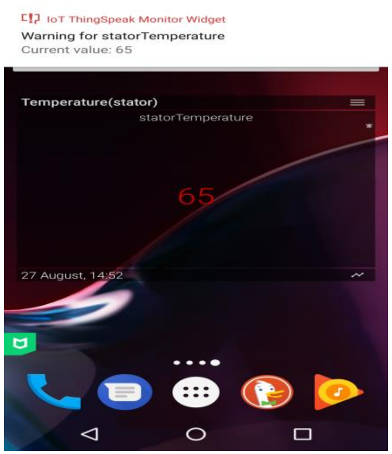
Output Window Displaying The Estimated Insulation Life

Monitoring Temperature Rise In Stator Winding

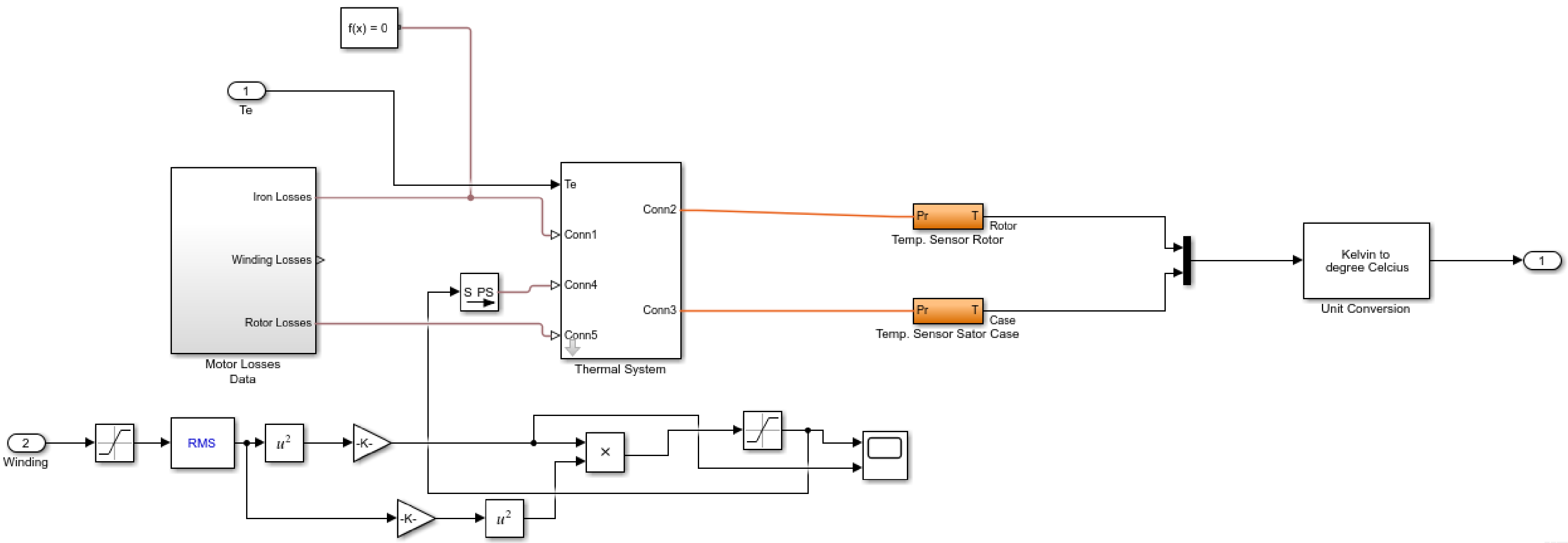


Stator Winding Temperature being detected by MLX90614

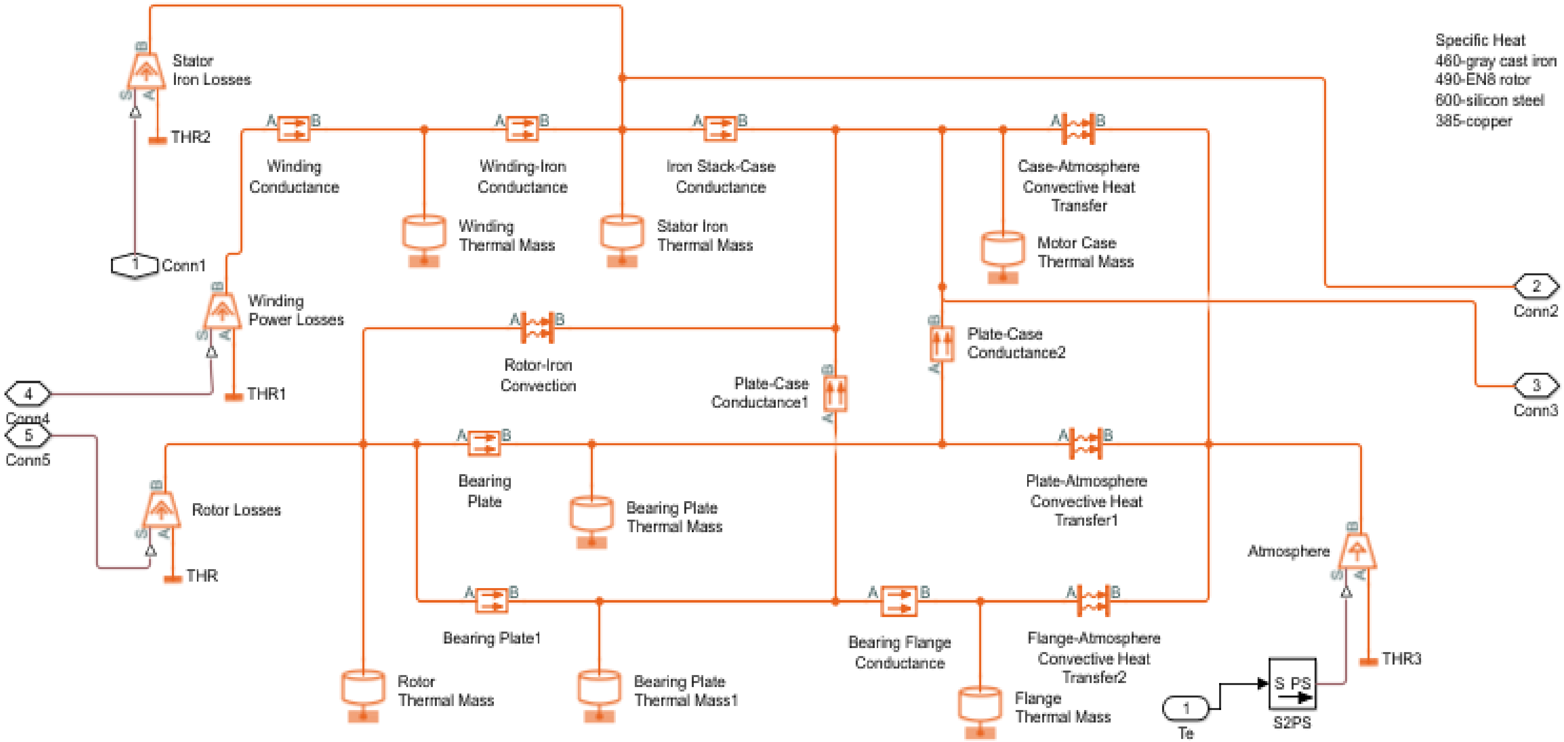




Thermal Sub System-Digital Twin



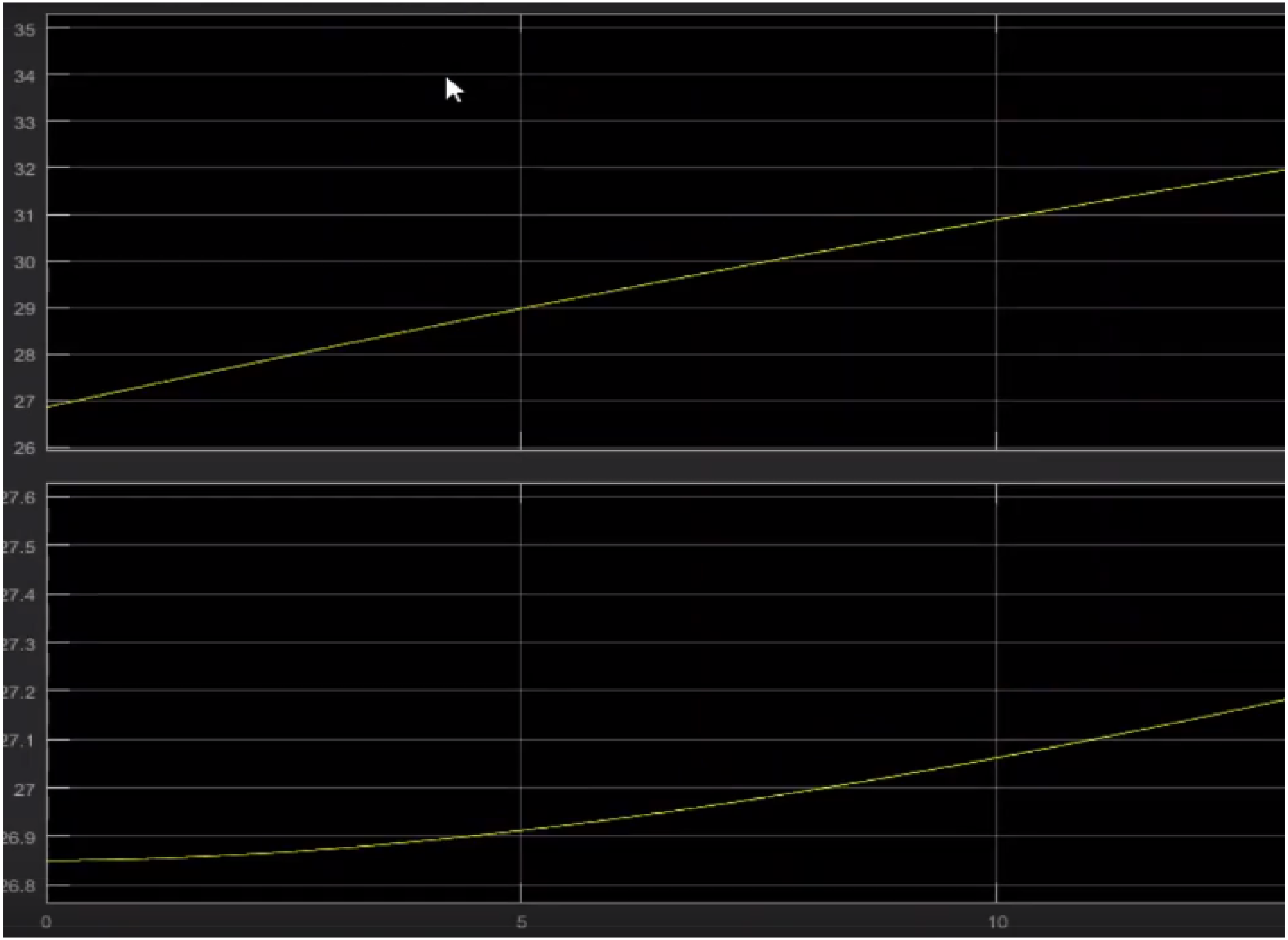
Heat Transfer-Digital Twin



Specific Heat
460-gray cast iron
490-EN8 rotor
600-silicon steel
385-copper

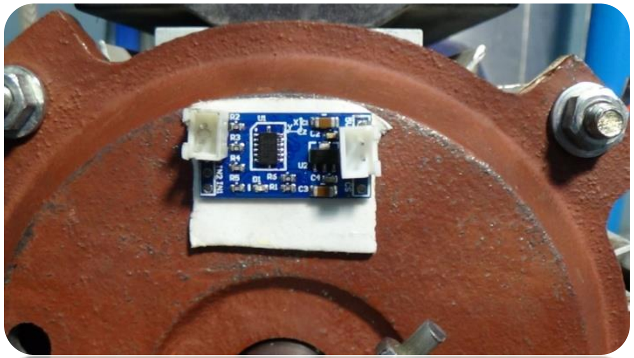
Conductance
385 -Winding W/(m*K)
31-silicon
53.3-cast iron
45-bearing plate

Temperature Rise Waveform

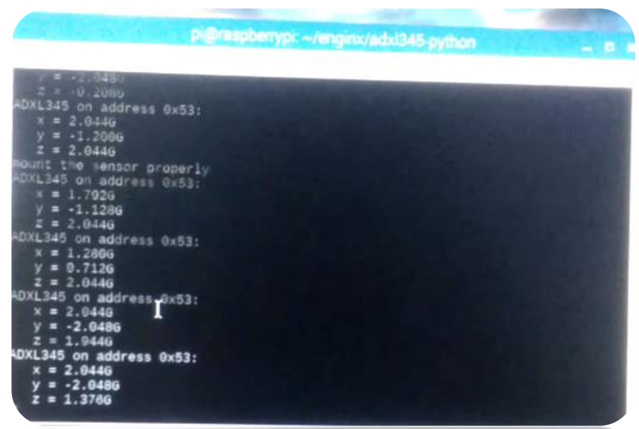


VIBRATION ANALYSIS

Vibration Analysis



ADXL345 mounted on the casing



Vibration Analysis

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MATLAB

Transfer learning in MATLAB

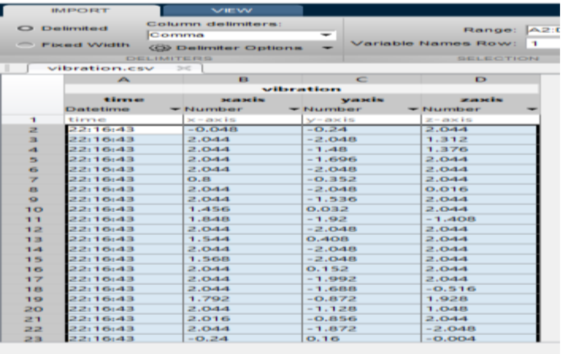
Predicting Motor Status From Vibration Data Using CNN

Motor Status Good Or Bad

VIBRATION ANALYSIS:

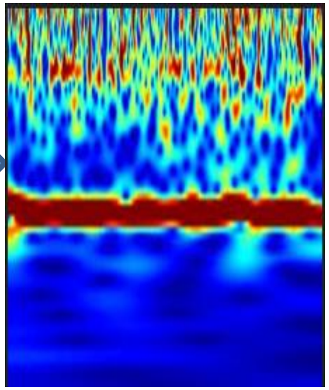
Vibration data → Continuous wavelet transform of the data and plot the cwt → CNN

VIBRATION ANALYSIS:

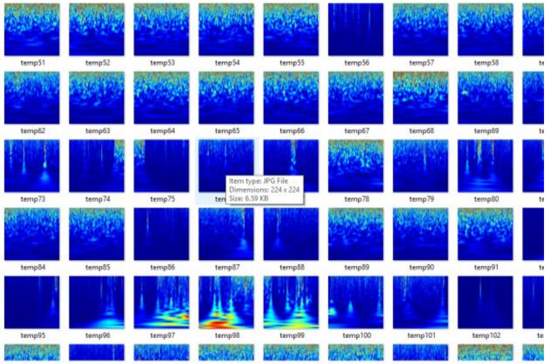


	A	B	C	D
	vibration			
	time Datetime	xaxis Number	yaxis Number	zaxis Number
1	time	x-axis	y-axis	z-axis
2	22:16:43	-0.048	-0.24	2.044
3	22:16:43	2.044	-2.048	1.312
4	22:16:43	2.044	-1.48	1.376
5	22:16:43	2.044	-1.696	2.044
6	22:16:43	2.044	-2.048	2.044
7	22:16:43	0.8	-0.352	2.044
8	22:16:43	2.044	-2.048	0.016
9	22:16:43	2.044	-1.536	2.044
10	22:16:43	1.456	0.032	2.044
11	22:16:43	1.848	-1.92	-1.408
12	22:16:43	2.044	-2.048	2.044
13	22:16:43	1.544	0.408	2.044
14	22:16:43	2.044	-2.048	2.044
15	22:16:43	1.568	-2.048	2.044
16	22:16:43	2.044	0.152	2.044
17	22:16:43	2.044	-1.992	2.044
18	22:16:43	2.044	-1.688	-0.516
19	22:16:43	1.792	-0.872	1.928
20	22:16:43	2.044	-1.128	1.048
21	22:16:43	2.016	-0.856	2.044
22	22:16:43	2.044	-1.872	-2.048
23	22:16:43	-0.24	0.16	-0.004

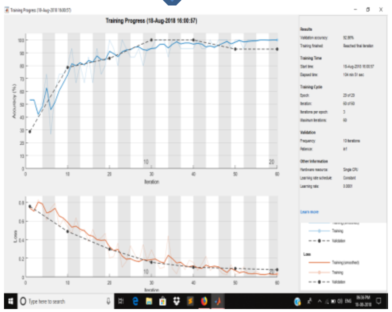
Vibration data



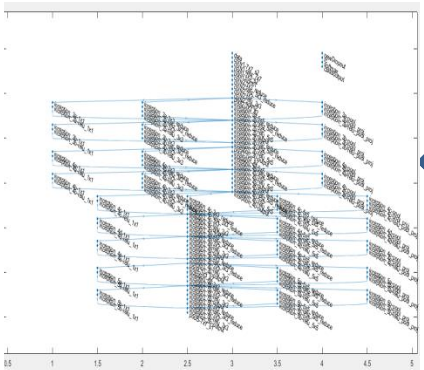
CWT of the data and plot the CWT



Create image data store



Training the CNN



Motor status

GOOD
Or
BAD

VIBRATION ANALYSIS:

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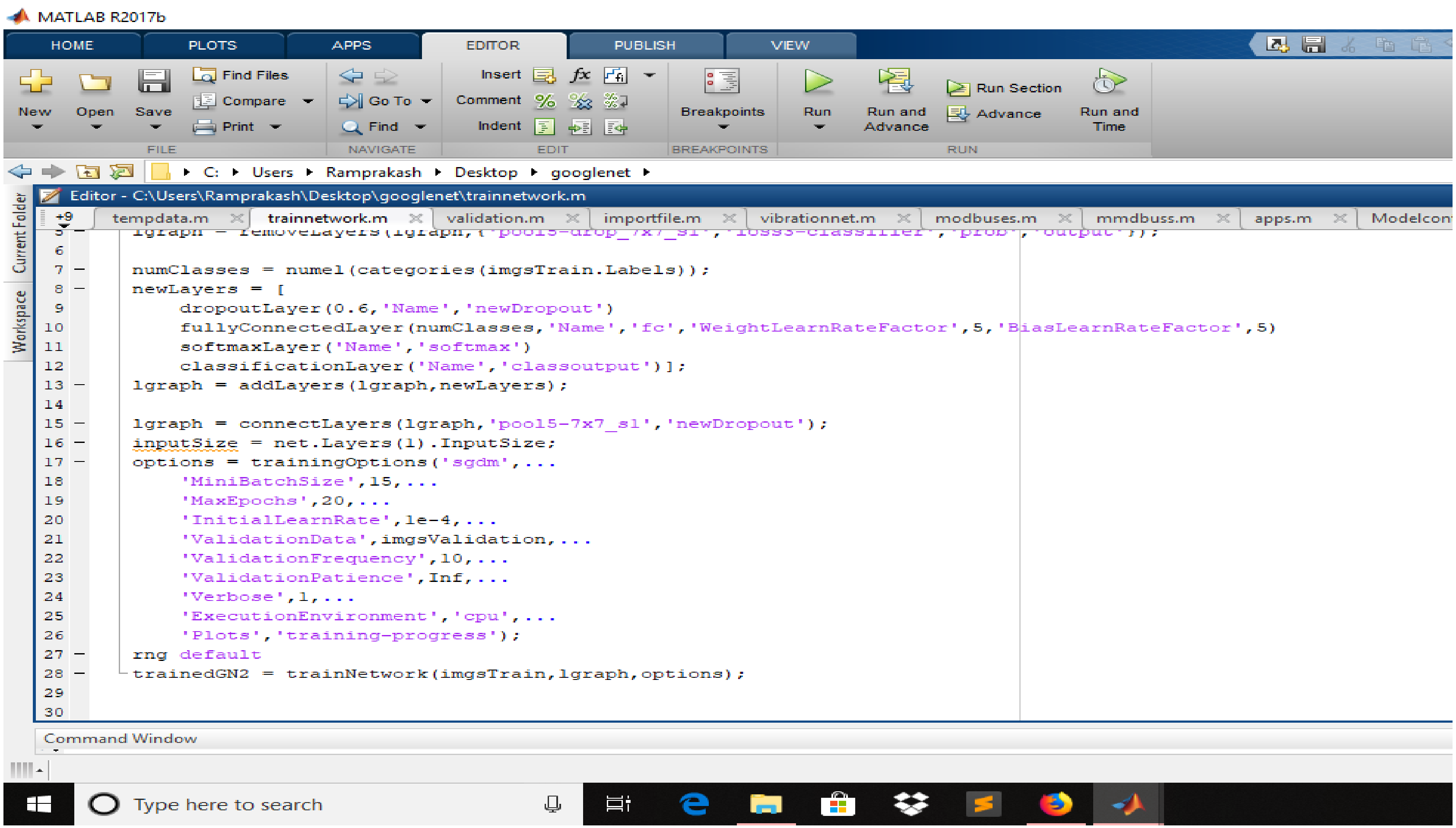
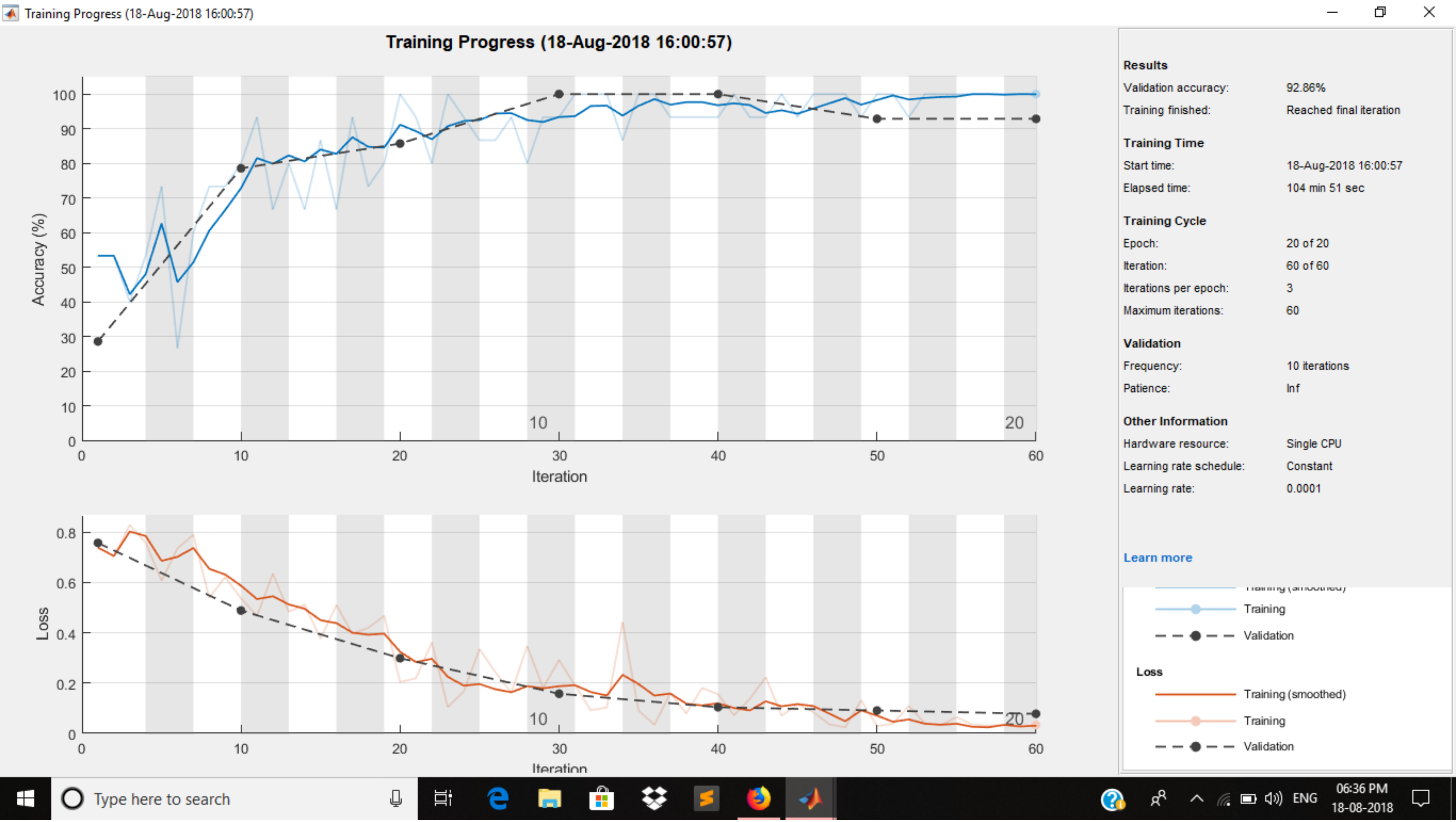
Code snippets for training

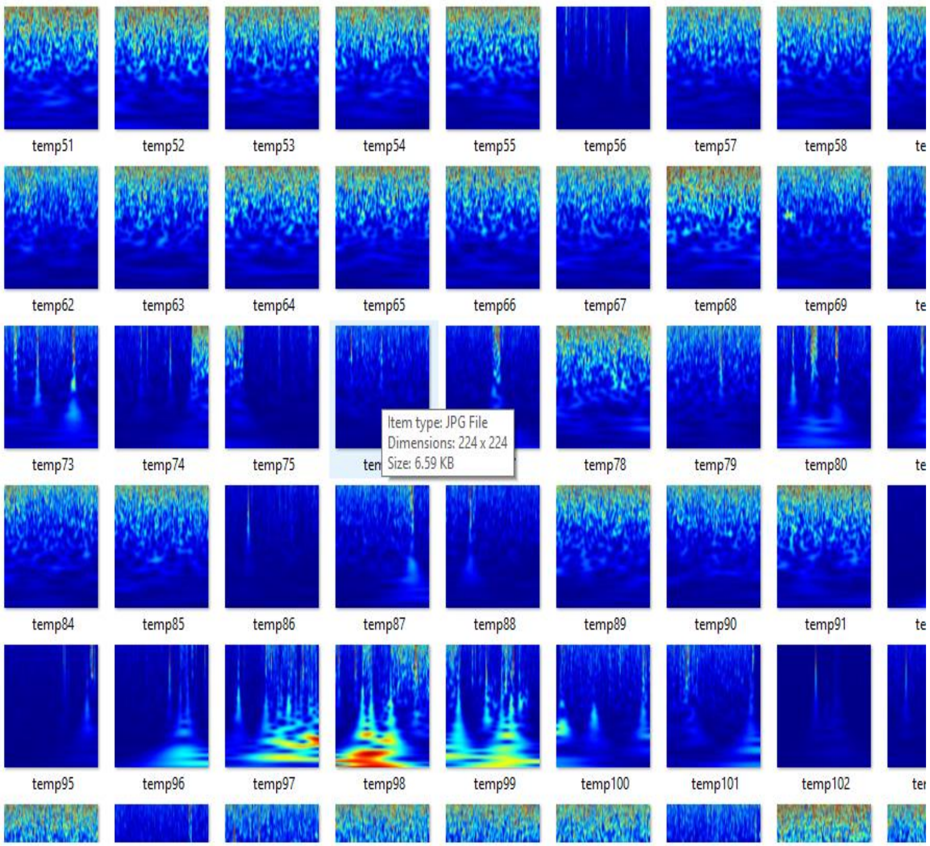


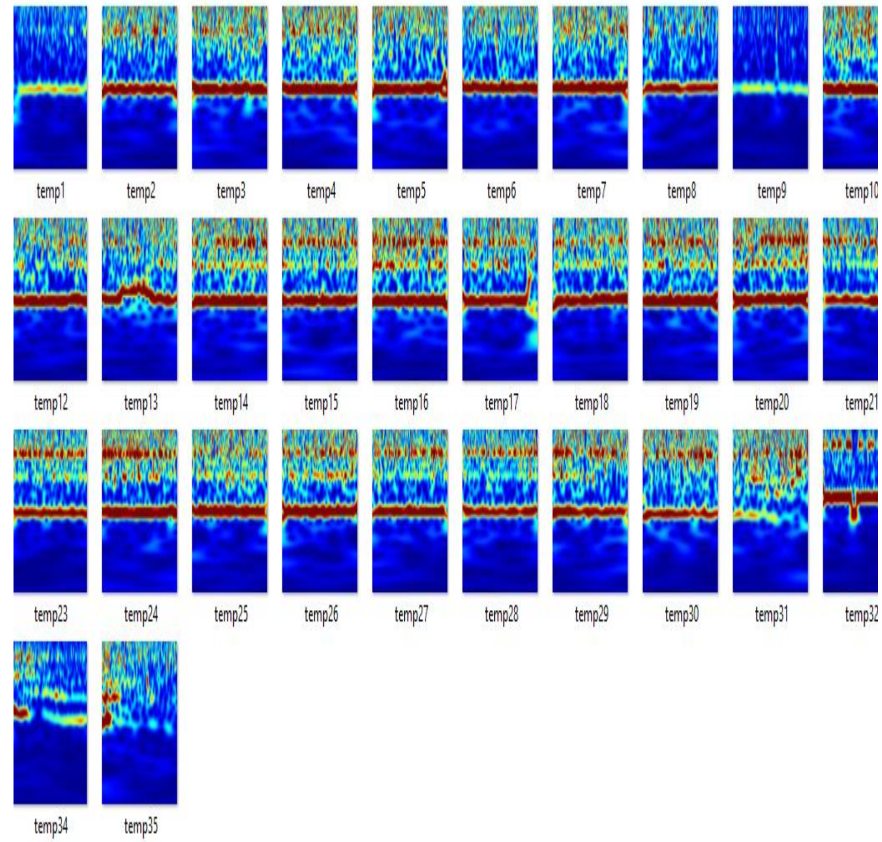
VIBRATION ANALYSIS:



VIBRATION ANALYSIS:

DATA SET





VIBRATION ANALYSIS:

- First few layers of the CNN
  - Input Layer 224*224*3
  - conv1-7x7_s2 64 7*7*3
  - conv1-relu_7x7 ReLu
  - pool1-3x3_s2 3*3 max pooling
- Last four layers of the CNN
  - Dropout layer
  - Fully connected layer
  - Softmax layer
  - Class output layer
  - Vibration.pptx (detailed explanation of ML)

BUSINESS PLAN

Why Smart Slurry Pumping System?

- **Slurry is one of the most challenging materials for a pump to handle.**

- **This is due to uncertainty in the nature of suspended matter.**

- **Hence the motor would be subjected to fluctuating loading conditions.**

Customer Requirement Identification

- Survey is taken from our local industries.
- Continuous monitoring of vibration is required.
- Continuous monitoring of insulation temperature is required.
- Monitoring of standard electrical parameters such as voltage, current, frequency and harmonic distortions are also required
- Retrofitting is most important

Different types of fault in rotating machines in percentage

Causes of different faults

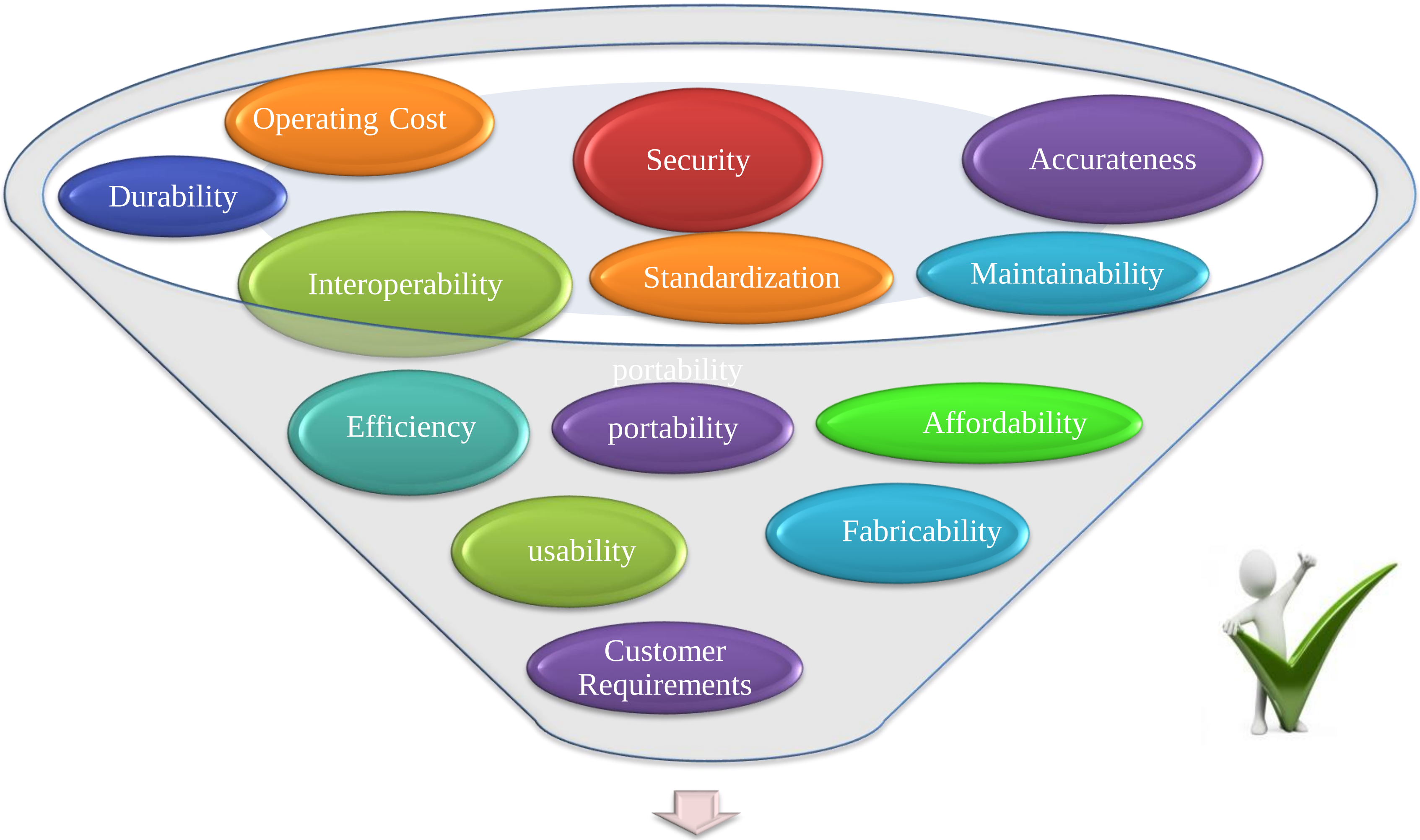
Reason routinely highlighted for all faults are:

Thermal stress – Temperature rise

Mechanical stress – Vibration

Electrical stress – Faults and harmonics

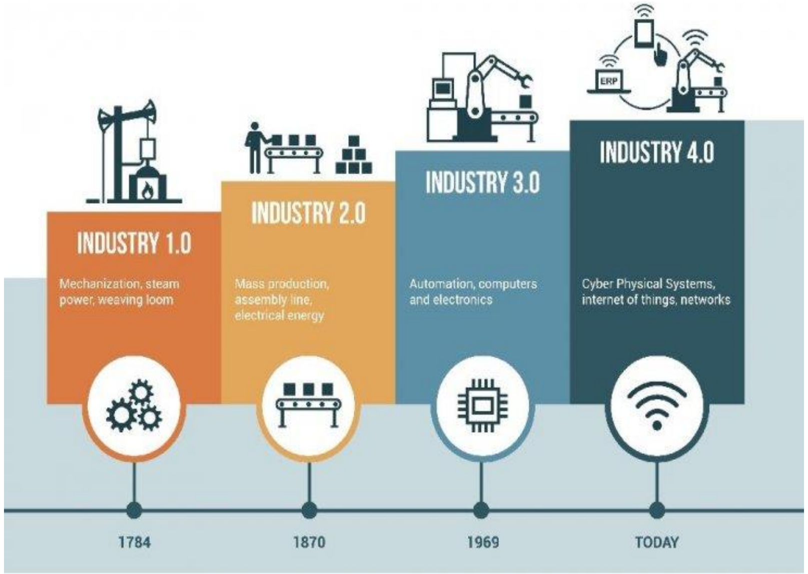
Benefits Of The System

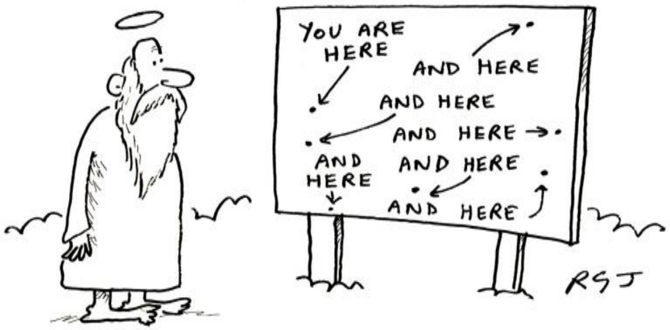


Smart Slurry Pumping System

Uniqueness of the system

- **Industry 4.0**
- **Centralized operation**
- **Less maintenance**
- **Digital Twin**
- **Cloud computing technology**
- **Parallel processing of all parameters.**
- **Generalized Solution to problem of industrial omnipresent i.e. motor.**

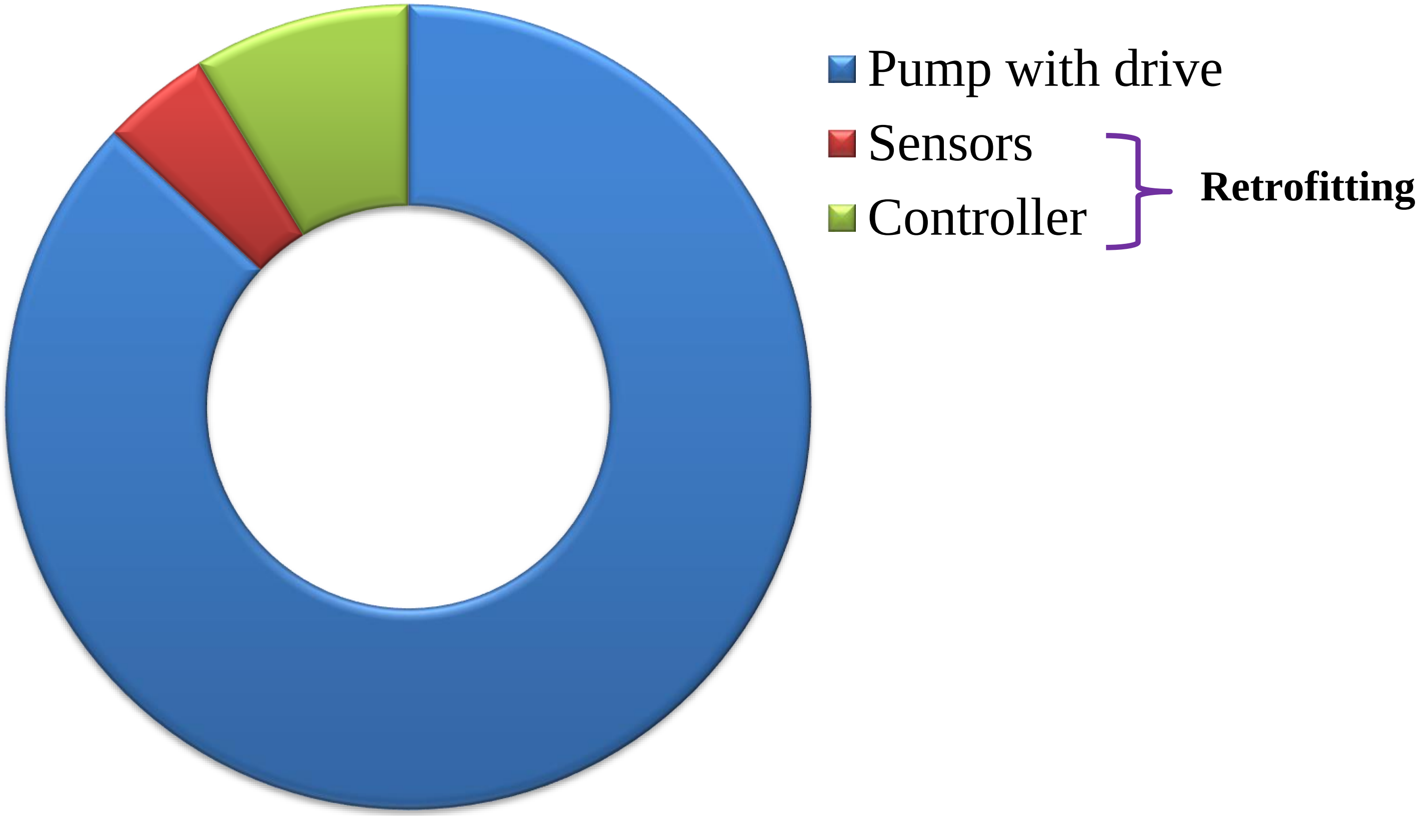




Bill of Materials

S. No.	Components	Amount (Rs.)
1	Tri-axial accelerometer	500
2	Non-contact type temperature sensor	500
3	Contact type temperature sensor	200
4	Raspberry Pi 3 Model B	3000
5	Energy management unit	10000
6	Software development	20000
	TOTAL	34200

Implementation Cost Distribution



Improving Reliability and Uptime

The Digital Twin can act before product failure begins.

Better product reliability, increased uptime and lower maintenance cost creates customer value.

- Tease

What is the problem?

- Please

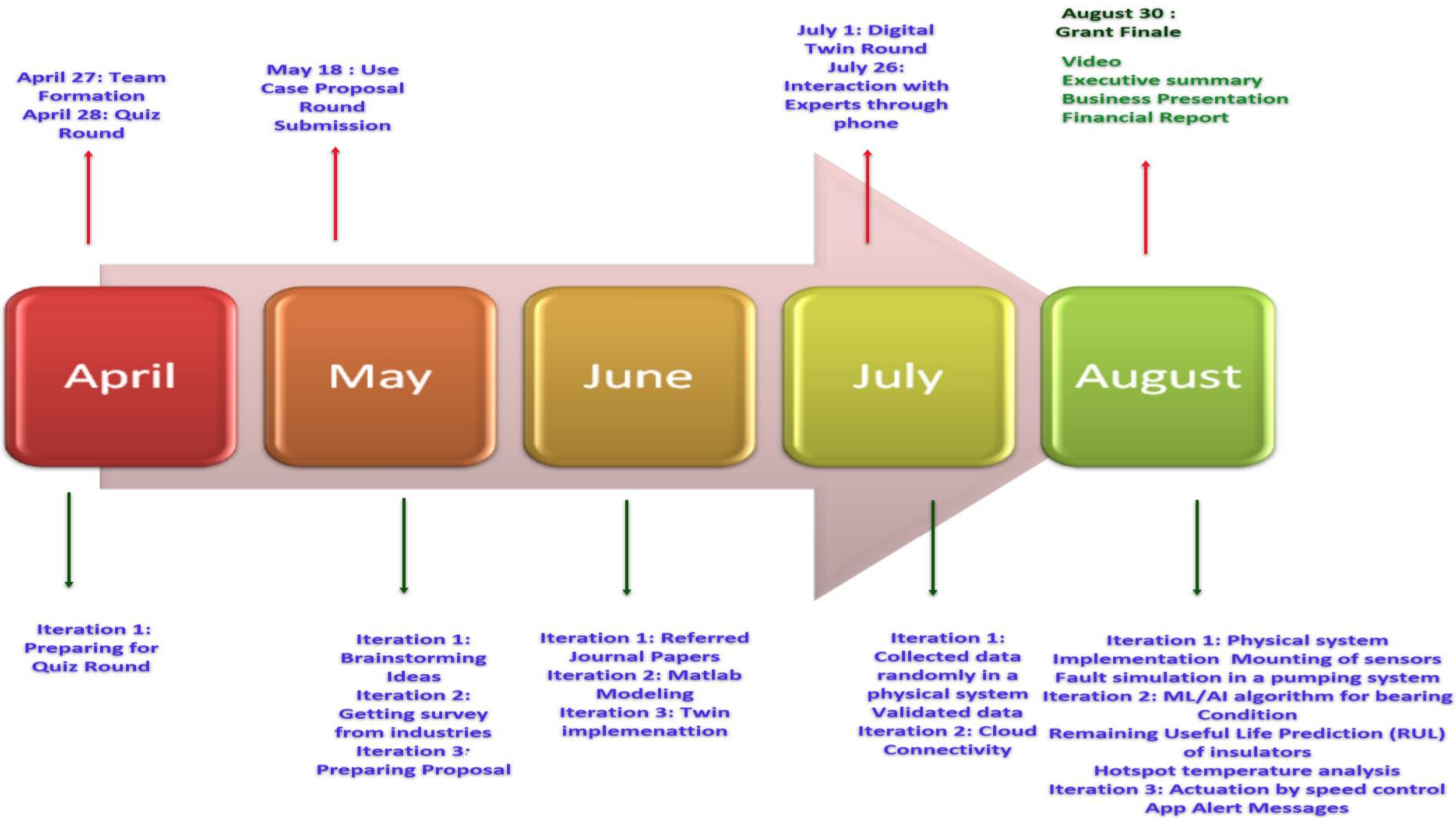
What is the solution?

- Seize

What are the opportunities?

Demonstrating Prototype.

Milestones


April 27: Team Formation
April 28: Quiz Round
May 18 : Use Case Proposal Round Submission
July 1: Digital Twin Round
July 26: Interaction with Experts through phone
August 30 : Grant Finale
Video
Executive summary
Business Presentation
Financial Report
April
May
June
July
August
Iteration 1: Preparing for Quiz Round
Iteration 1: Brainstorming Ideas
Iteration 2: Getting survey from industries
Iteration 3: Preparing Proposal
Iteration 1: Referred Journal Papers
Iteration 2: Matlab Modeling
Iteration 3: Twin implemenattion
Iteration 1: Collected data randomly in a physical system
Validated data
Iteration 2: Cloud Connectivity
Iteration 1: Physical system Implementation Mounting of sensors
Fault simulation in a pumping system
Iteration 2: ML/AI algorithm for bearing Condition
Remaining Useful Life Prediction (RUL) of insulators
Hotspot temperature analysis
Iteration 3: Actuation by speed control
App Alert Messages

References

- **Ma, J., Wu, J., & Wang, X. (2018). Fault diagnosis method based on wavelet packet-energy entropy and fuzzy kernel extreme learning machine. Advances in Mechanical Engineering, 10(1), 1687814017751446.**
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- **Schoen RR, Habetler TG, Kamran F, Bartheld RG (1995) Motor bearing damage detection using stator current monitoring. IEEE Trans Ind Appl 31(6):1274–1279**
- **Tavner PJ (2008) Review of condition monitoring of rotating electrical machines. IET Electr. Power Appl 2(4), 215**
- **Omar Badran, Hussain Sarhan,Bilal Alomour. Thermal performance analysis of induction motors.International Information and Engineering Technology Association.**

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