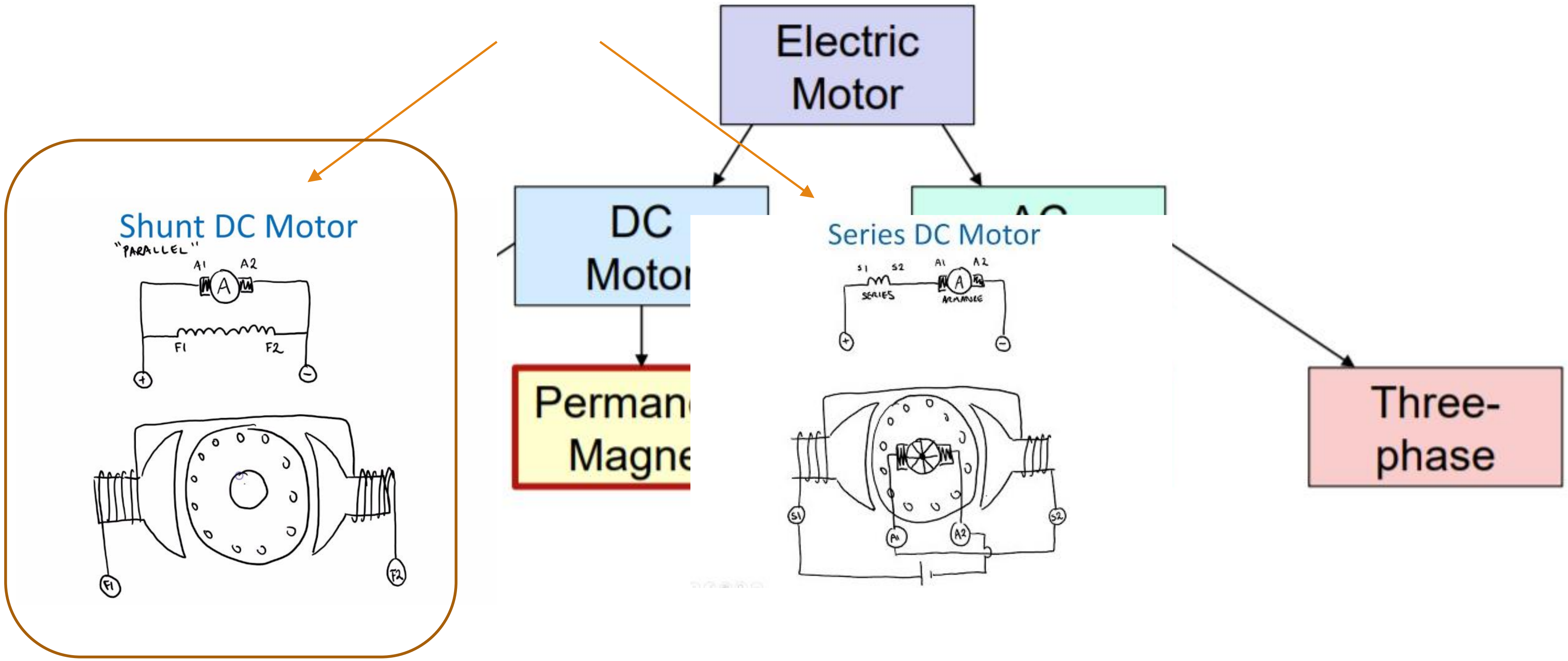

# Speed Control of DC Motors

JIANNING ZHUANG

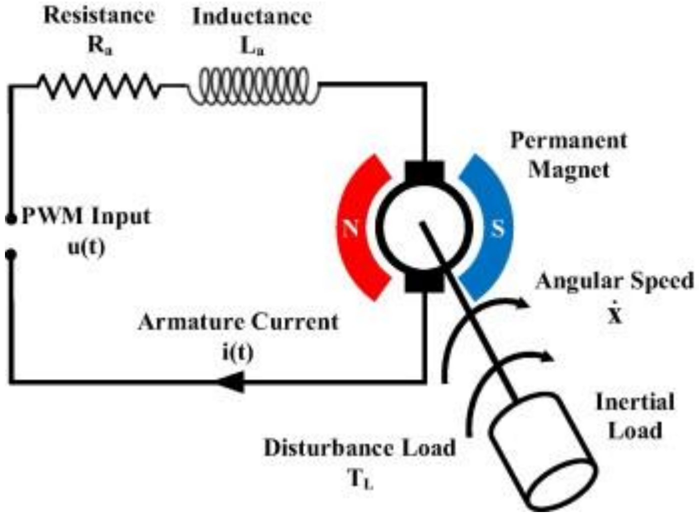
# Classification of Motors




[1]

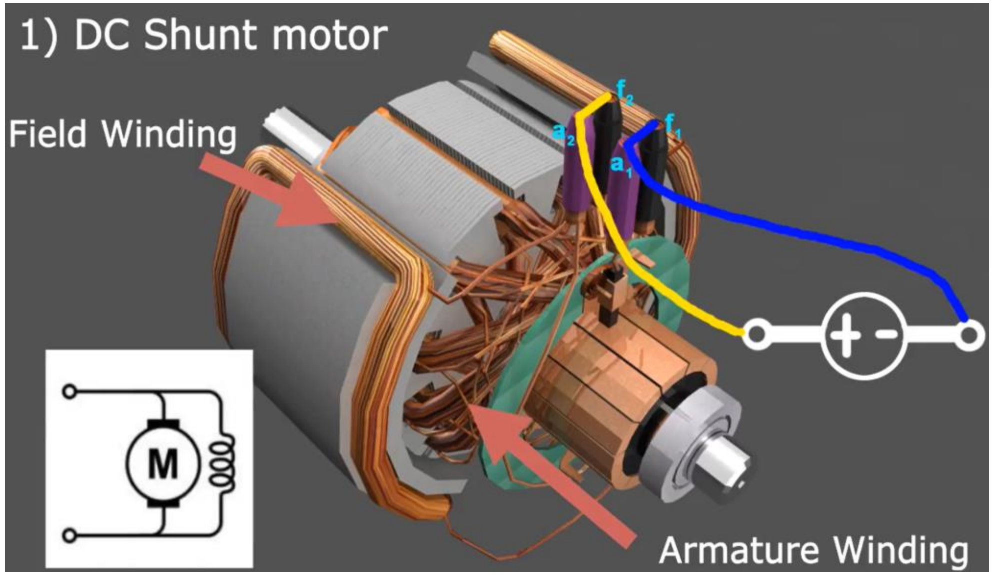
[2]

## Permanent Magnet DC Motor



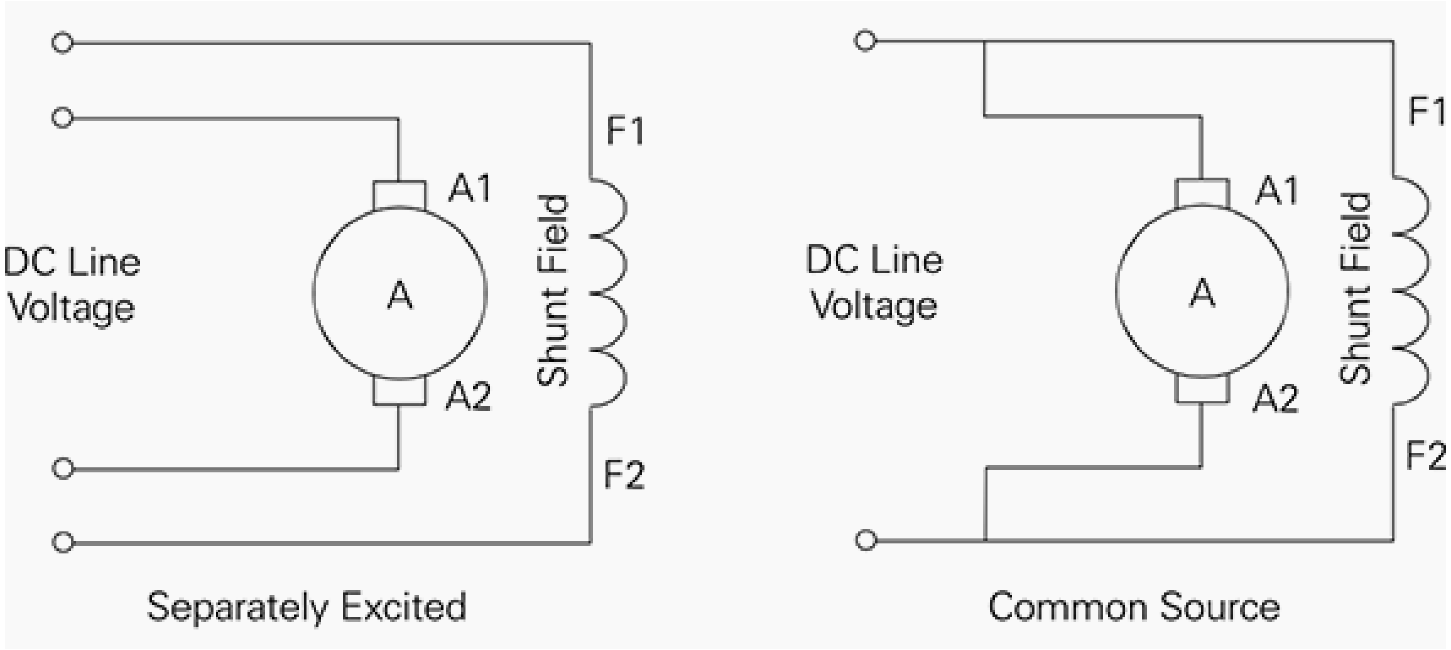

[3]

## DC Shunt Motor



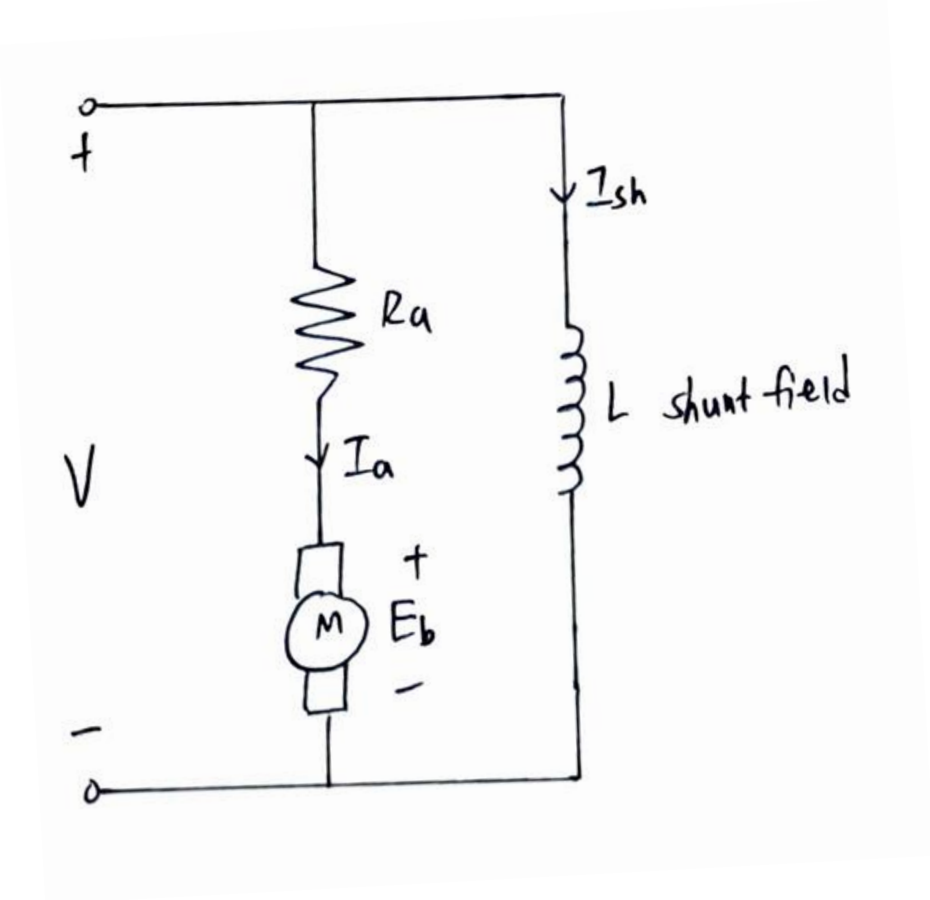

[4]

# Circuit Equivalent of DC Shunt Motor




[5]

# Deriving Speed Equation of DC Shunt Motor




$$V = E_b + I_a R_a$$

$$E_b = k_e \emptyset \omega$$

$$E_b = \frac{P \emptyset N Z}{60A}$$

$$\omega = \frac{V - I_a R_a}{k_e \emptyset}$$

[6]

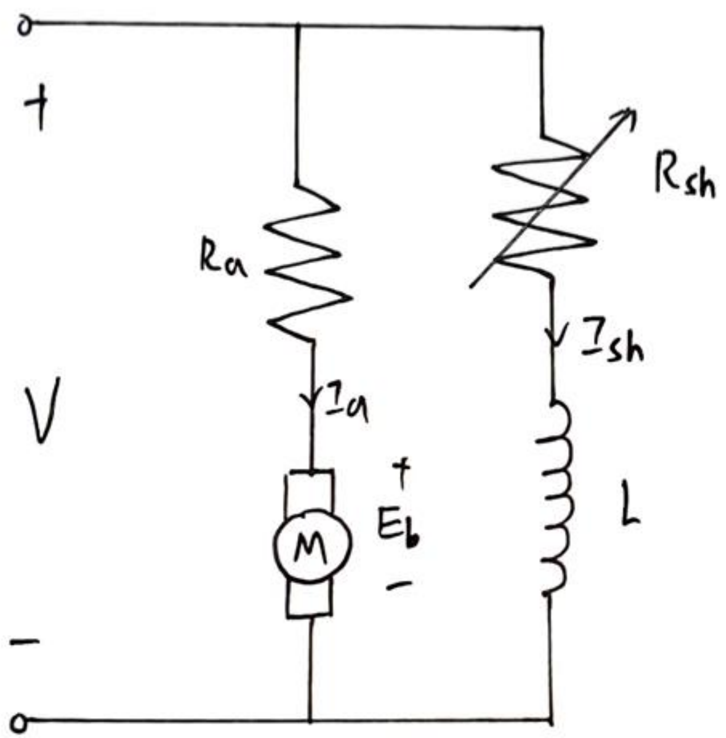
Recall the speed equation for PMDC motors

$$\boxed{\omega = \frac{V_m}{K_e} - \frac{R_m I_m}{K_e}}$$

$$\omega = \frac{V - I_a R_a}{k_e \emptyset}$$

# 1) Flux Control Method

$$\omega = \frac{V - I_a R_a}{k_e \emptyset}$$




$R_{sh} \uparrow \qquad I_{sh} \downarrow$

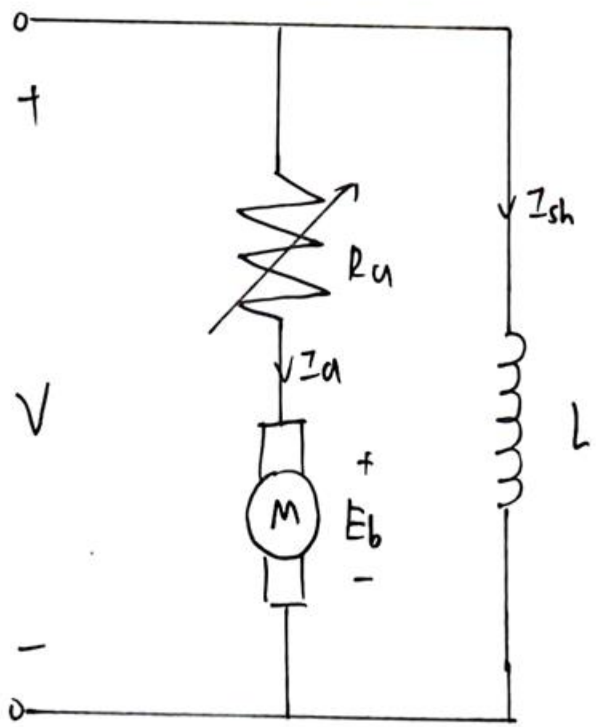
$I_{sh} \downarrow \qquad \emptyset \downarrow$

$\omega \text{ inversely proportional to } \emptyset$

$\emptyset \downarrow \qquad \omega \uparrow$

## 2) Armature Control Method

$$\omega = \frac{V - I_a R_a}{k_e \emptyset}$$




$$T_a = k_T I_a \emptyset$$

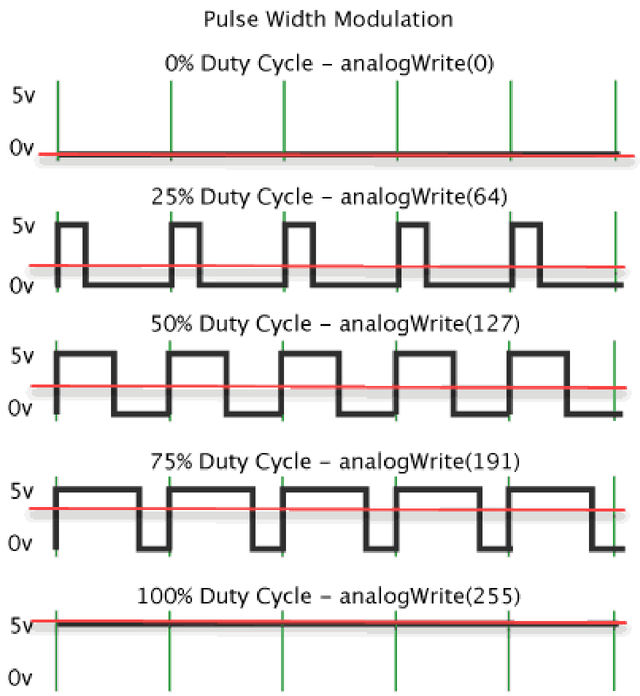
$$\omega = \frac{V}{k_e \emptyset} - \frac{R_a}{k_e k_T \emptyset^2} T_a$$

$R_a \uparrow \qquad \omega \downarrow$

[7]

# 3) Voltage Control Method

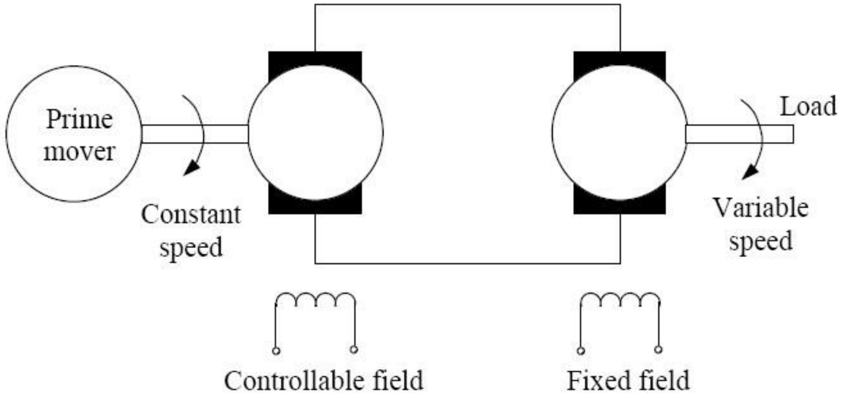
$$\omega = \frac{V - I_a R_a}{k_e \emptyset}$$



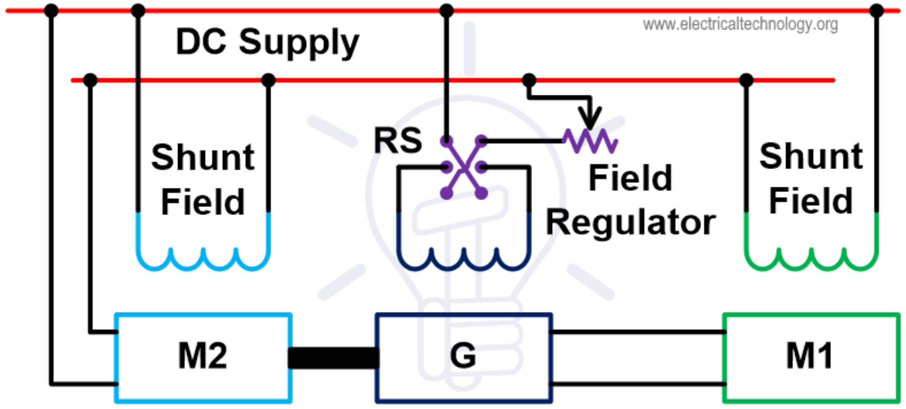

$\omega$ *is proportional to* $V$

[8]

# Ward Leonard System




[9]




[10]

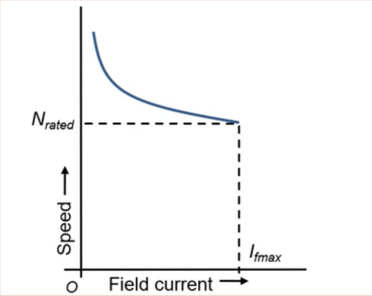
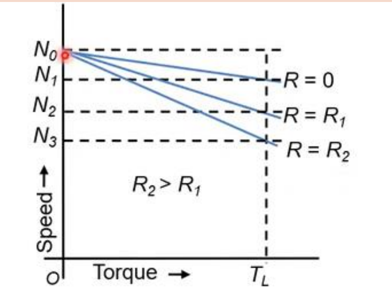
# Speed Control

| Flux Control | Armature Control | Voltage Control |
|---|---|---|
| • Only produce speeds higher than original rated speed<br>• Lowest speed when variable R is 0 | • Only produce speeds lower than original rated speed<br>• Highest speed when variable R is 0 | • Can operate at any speed up to maximum<br>• Bi-directional<br>• Smooth change in speed |

# Efficiency

| Flux Control | Armature Control | Voltage Control |
| --- | --- | --- |
| • Efficient<br>• Shunt field current $I_{sh}$ is very small<br>• Power loss $I^2R$ is low even with high variable resistance | • Inefficient<br>• Armature current $I_a$ is much larger<br>• Power loss $I^2R$ is high as variable resistance carries full armature current | • Efficient<br>• PWM and Ward Leonard have minimal resistance losses |

# Other Limitations

| Flux Control | Armature Control | Voltage Control |
|---|---|---|
| • Limit on maximum speed<br>• Low current/flux may case speed to become dangerously high<br>• Instability and poorer commutation<br><br><br>[11] | • Poor speed regulation<br><br><br>[12] | • Ward Leonard system requires a special motor-generator set<br>• Higher cost<br>• Larger size and weight |

# Summary

$$\omega = \frac{V - I_a R_a}{k_e \emptyset}$$

Flux Control Method

$\emptyset$

Armature Control Method

$R_a$

Voltage Control Method

$V$

# References


[1]  Petre Vree. “Shunt DC Motor Connections," *YouTube*, Dec 18, 2016. [Video file]. Available: https://www.youtube.com/watch?v=6RAE-Y7cQG0. [Accessed: Oct 4, 2020].

[2]  Petre Vree. “Series DC Motor Connections," *YouTube*, Dec 17, 2016. [Video file]. Available: https://www.youtube.com/watch?v=gSCv0rj2uYs. [Accessed: Oct 4, 2020].

[3] Rashidi, B., Esmaeilpour, M. and Homaeinezhad, M., 2015. *Precise Angular Speed Control Of Permanent Magnet DC Motors In Presence Of High Modeling Uncertainties Via Sliding Mode Observer-Based Model Reference Adaptive Algorithm*. [online] Science Direct. Available at: <https://www.sciencedirect.com/science/article/abs/pii/S0957415815000549> [Accessed 5 October 2020].

[4] Sourabh Sharma. “Types of DC Motors," *YouTube*, Aug 11, 2018. [Video file]. Available: https://www.youtube.com/watch?v=TnZAHlyW1E8. [Accessed: Oct 4, 2020].

[5] Csanyi, E., 2015. *4 Types Of DC Motors And Their Characteristics*. [online] EEP - Electrical Engineering Portal. Available at: <https://electrical-engineering-portal.com/4-types-of-dc-motors-and-their-characteristics> [Accessed 5 October 2020].

[6] Daware, K., 2014. *Speed Control Methods Of DC Motor*. [online] Electricaleasy.com. Available at: <https://www.electricaleasy.com/2014/01/speed-control-methods-of-dc-motor.html> [Accessed 6 October 2020].

[7]  Teresa, O., “DC Drives," *Power Electronics and Drives*, pp. 509-547, 2018. [Online]. Available http://www.philadelphia.edu.jo/academics/mlazim/uploads/ chapter11pdf. [Accessed 6 October 2020].

[8] Heath, J., 2017. *PWM: Pulse Width Modulation: What Is It And How Does It Work?*. [online] Analog IC Tips. Available at: <https://www.analogictips.com/pulse-width-modulation-pwm/> [Accessed 6 October 2020].

[9] Moore, R. and Drakos, N., 2008. *AC Ward Leonard Drive Systems*. [online] Mypages.iit.edu. Available at: <http://mypages.iit.edu/~qzhong2/ACDrive_web/ACDrive_web.html> [Accessed 6 October 2020].

[10] ELECTRICAL TECHNOLOGY. 2020. *Speed Control Of DC Motor - Voltage, Rheostatic & Flux Control Methods*. [online] Available at: <https://www.electricaltechnology.org/2020/05/speed-control-dc-motor.html#advantages-disadvantages-if-ward-leonard-method> [Accessed 6 October 2020].

# References

[11]  Athul R Padke. “Speed control of DC shunt motors," *YouTube*, May 1, 2020. [Video file]. Available: https://www.youtube.com/watch?v=BtPUCuR3XQE. [Accessed: Oct 4, 2020].

[12] ELECTRICAL TECHNOLOGY. 2020. *Speed Control Of DC Motor - Voltage, Rheostatic & Flux Control Methods*. [online] Available at: <https://www.electricaltechnology.org/2020/05/speed-control-dc-motor.html#advantages-disadvantages-if-ward-leonard-method> [Accessed 6 October 2020].