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ELEVATOR DESIGN

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PREPARED AT DEPARTMENT OF MECHATRONICS ENGINEERING

ELEVATOR DESIGN

FINAL PROJECT REPORT

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Table of Contents

Table of Figures

ACKNOWLEDGEMENTS

During Electrical Drive System Course, we have learned how to control the speed, torque and direction of an electrical motor, the differences between the electrical drive systems and their working principles. Why we choose Elevator Design as a final Project of this course? We thought that is a great challenge for us, as a team to understand the working principles of elevators.We would like to thank our Project Advisor Assoc.Prof.Dr.Cenk Ulu for transferring the experience of this course to us, as well as providing us a chance to apply this theoretical knowledge in a term project that challenged us professionally. We are hoping that our outputs from this course and this teamwork will guide us throughout our academic & professional career.

Our best regards,

ABSTRACT

In this term project report a brief introduction to Elevator Design has been made following it's application in the industry. From there we have discussed the overall types of elevators and its' drive systems. We have briefly addressed the working principle of the system and followed it by explaining the mathematical approach of how to run this system according to our problem definition. We have also demonstrated a method based on optimization rules to select the best candidate for an electrical motor to be used in the elevator system on the MATLAB platform.

1. INTRODUCTION

In this report, we will give brief information about the elevator’s history, working principles, elevtrical drive types, calculation of our elevator design, simulation outcomes. Basically, we will show our work, how we decide to start of this project and what can be done in the future.

1.1 The History of Elevators

The primary rudimentary lifts showed up within the third century B.C. These lifts might be powered by people, horses, or water-driven frameworks. A raise frequently utilized a framework of ropes and pulleys to lift up individuals or huge objects like pieces of stone and wood to be utilized in building development. Without lifts, numerous antiquated landmarks would not be here nowadays.

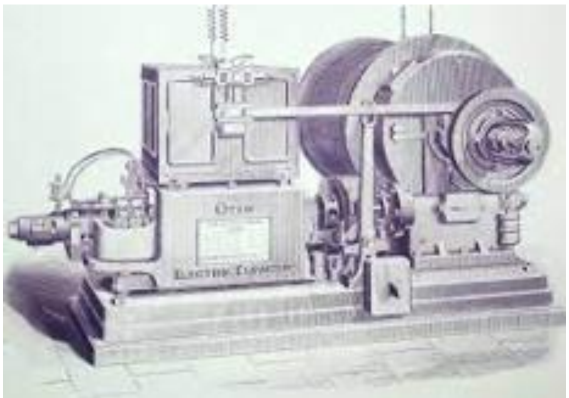


Figure 1.1-Historic Elevator of Otis Brothers

Steam Hydraulic Elevators : Another advancement of the lift presented the utilization of steam hydrodynamics to control the lift framework. Steam water powered frameworks came almost amid the Mechanical Insurgency in reaction to the ought to move expensive sums of crude materials like stumble and coal. These lifts were able to lift bulk materials out of mines and manufacturing plants. English modelers Ice and Stutt designed a lift called the Teagle, which was an effective lift that utilized a counterweight to donate it an additional boost of power. These steam-powered lifts are driven to developments just like the lift shaft, driving to machines that are more recognizable as the lifts we utilize nowadays.

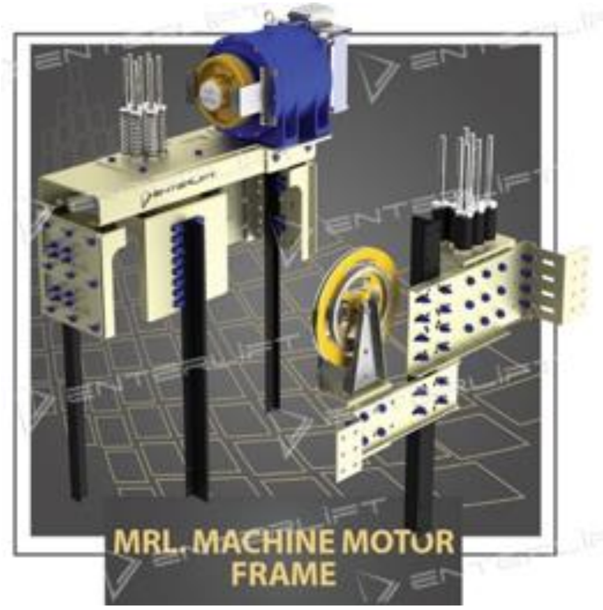


Figure 1.2-MRL Elevator motor

Motor elevators: After the innovation of power, it wasn't long some time recently lifts joined the positions of apparatus fueled by engines. German creator Werner von Siemens designed the primary electric lift in 1880. This lift was quicker, more secure, and more effective than the steam lifts of the past. Straight to the point Sprague included security highlights, floor control, increasing speed control, and other imperative components that to this day keep our lifts secure and exceedingly utilitarian.

1.2 Industry Applications

The advancement of elevators was driven by the requirement for development of crude materials counting coal and amble from slopes. The innovation created by these industries and the introduction of steel pillar development worked together to supply the traveler and cargo lifts in use nowadays. Beginning within the coal mines, by the mid-19th century elevators were worked with steam control and were utilized for moving products in bulk in mines and manufacturing plants. These steam driven gadgets were soon being connected to a diverse set of purposes – in 1823, two planners working in London, Burton and Hormer, built and worked a novel visitor fascination, which they called the "ascending room". It raised paying clients to an impressive stature within the center of London, permitting them a radiant all encompassing see of downtown.

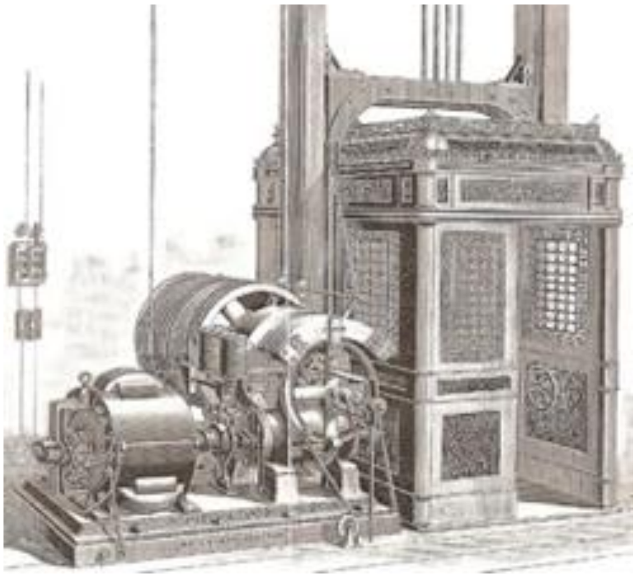


Figure 1.3- Historic Elevator of Otis Brothers

The first elevator shaft went before the primary lift by four a long time. Development for Dwindle Cooper's Cooper Union Establishment building in Modern York began in 1853. A lift shaft was included within the plan, since Cooper was certain that a secure traveler lift would soon be invented.The shaft was round and hollow since Cooper thought it was the foremost proficient plan. Afterward, Otis planned an uncommon lift for the building. The first electric lift was built by Werner von Siemens in 1880 in Germany. The creator Anton Freissler created the thoughts of von Siemens and built up an effective endeavor in Austria-Hungary. The security and speed of electric lifts were essentially upgraded by Straight to the point Sprague which included floor control, programmed lifts, increasing speed control of cars, and protections. His lift ran speedier and with bigger loads than water powered or steam lifts, and 584 electric lifts were introduced some time recently Sprague sold his company to the Otis Lift Company in 1895. Sprague too created the thought and innovation for numerous lifts in a single shaft. By 1900, completely automated elevators were available, but passengers were reluctant to use them. A 1945 elevator operator strike in New York City, and adoption of an emergency stop button, emergency telephone, and a soothing explanatory automated voice aided adoption.

1.3 Scope of This Project

The Project consists of investigating elevator drive systems and concepts in general. General purpose is to analyse electrical condition, electrotechnical design, rotor, mechanical design, Ward Leonard, control, assembling, environment, machine elements, and thermal conditioning.

2. ELEVATORS

In this section, we try to learn how the elevator’s work, which types of elevators are exist and understand how we can use this information for our project design.

2.1 Working Principle

For modern elevators, control systems have been modified to improve speed and safety. In most circumstances, elevators will balance the car by using counterweight and 40 percent of the maximum rated load.

The counterweight's principal purpose is to limit the amount of weight that the engine has to lift while keeping the elevator in control and the cables intact. The car elevator is composed of steel to ensure its endurance and strength. A spanned side-to-side elevator shaft holds the pulley used by the hoist rope in place. A set of steel bars suspended above the elevator car control the spinning.

An elevator or lift works on the same concept as a pulley system. The water is drawn from the well using a pulley system. A bucket, a rope, and a wheel can all be used in this pulley system. A bucket is attached to a rope that runs the length of a wheel. This might make drawing water from the well a breeze. Similarly, modern elevators operate on the same principle. However, the fundamental difference between the two is that pulley systems are manually operated, whereas elevators use sophisticated mechanics to handle the elevator's load.

Figure 2.1- Pulley system for drawing water from the well

An elevator is essentially a metal box of various designs that is attached to an extremely strong metal rope. In the engine room, the robust metal rope runs through a sheave on the elevator. A sheave acts as a wheel in a pulley system, tightly grasping the metal rope. A motor can be used to control this arrangement. The motor can be triggered when the elevator goes up and down or stops when the switch is switched on.

The elevator can be built using a variety of elevator components or parts, which include the speed control system, electric motor, rails, cabin, shaft, manual and automatic doors, drive unit, buffers, and safety device, among others.

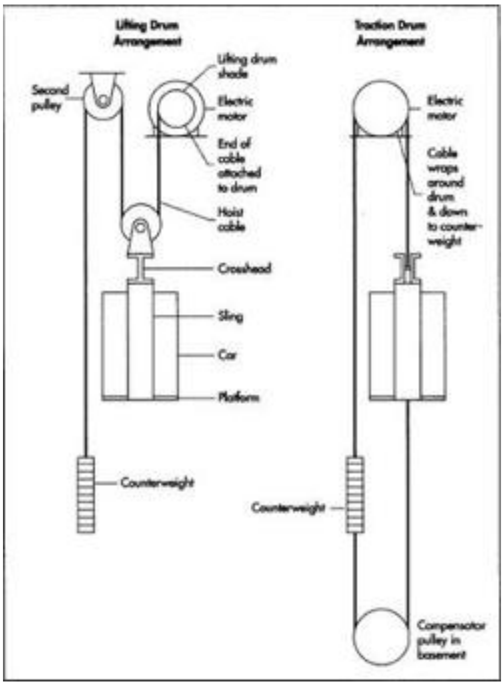


Figure 2.2- Elevator working principle diagram

2.2 Types of Elevators

The six variations of elevators utilized in many buildings are as follows:

2.2.1 Traction Elevators

Gearless and Geared Traction Elevators with Machine Rooms: Ropes are used to hoist these sorts of elevators, such as geared and gearless traction. The rope runs through a sheave connected to an electric motor on the elevator shaft's top. These are commonly seen in mid-to-high-rise elevators and have shorter travel periods than hydraulic elevators.

A counter weight will be used in the elevators to help them run more efficiently by countering the burden inside the elevator car, which could be passengers or equipment. Elevators that utilise geared traction will have a gearbox connected to a motor. The gearbox's job is to operate the ropes and drive the sheave. Geared traction elevators have the potential to travel at speeds of up to 500 feet per minute. A geared traction elevator has a travel distance of about 250 feet.

A sheave is directly coupled to the motor in gearless traction elevators. Gearless traction elevators might travel at speeds of up to 2000 feet per minute. A gearless elevator's maximum travel distance is roughly 2000 feet, making it ideal for high-rise structures. Typically, the initial cost of installation for gearless traction elevators is higher. Because gearless traction elevators are generally more efficient than geared traction elevators, their maintenance costs may remain stable.

Regularly inspecting the traction of the elevator sheaves and ropes for wear and tear is critical. These parts, such as cables and sheaves, might wear out, causing the elevator components to slip and lose traction. This can diminish the elevator's efficiency while also increasing the risk of using it.

Because traction elevators are constructed with a set length of rope, cable, and weight, they have a height restriction. New materials, such as carbon fiber, are being utilized in traction elevators to help them become stronger and lighter, allowing them to reach new heights.

2.2.2 Hydraulic Elevators

- Holed Elevators
- Hole-less Elevators
- Telescopic Elevators
- Non-Telescoping Elevators
- Roped Elevators

A hydraulic elevator's design incorporates a piston at the bottom to provide support. The piston uses hydraulic pressure to lift the elevator in tandem with a motor that controls the amount of oil (hydraulic fluid) in the piston. When the elevator descends, a speed valve operates to relieve pressure inside the piston.

These elevators are often found in buildings with no more than 8 stories and run at a pace of 150 feet per minute.

Typically, the machine room will be on the lowest floor, across from the elevator. Inside the pit, the hydraulic elevator will feature a piston that extends beneath the elevator floor. The piston retracts as the elevator descends. There are various versions, but the majority will have a telescoping piston that collapses and just requires a small hole within the pit to operate.

The hydraulic elevator has a travel distance of around 60 feet and can have a piston on each side of the cab if it is designed without a pit. The elevator can go up to 50 feet with telescoping pistons, but only up to 20 feet with non-telescoping pistons.

The cab is sometimes operated by a rope hydraulic elevator and piston, however this has a limit of about 60 feet.

The original cost and maintenance costs may be lower than for conventional elevators, but the hydraulic energy cost may be higher. Because the electric motor is working against gravity while pumping hydraulic fluid into the piston, this is the case. One of the disadvantages of hydraulic elevators is the possibility of fluid leakage and environmental dangers.

2.2.3 MRL Elevators

A traction elevator with no machine room over the elevator shaft is known as a Machine Room-Less Elevator. The machine room is usually at another location and can be reached for maintenance through the cab towards the top of the elevator. The control room, which is usually on the topmost landing adjacent to the elevator shaft, houses the control boxes.

Elevators without a machine room have a maximum travel distance of 250 feet and can reach speeds of 500 feet per minute. The MRL elevator will have identical startup and maintenance costs as geared traction elevators, but it will use less energy than a geared elevator. MRL elevators are popular in mid-rise structures with trip distances of less than 250 feet.

Building codes are one of the key reasons for the sluggish adoption of MRL elevators in the United States. The provisions pertain to the elevator's motor and its location within the elevator's hoistway. Building codes are always changing, so it's a good idea to check with your local code enforcement agency about MRL elevators.

2.2.4 Pneumatic Elevators

Pneumatic Elevators are also known as home elevators which we are using every single day. Air pressure within the shaft raises and lowers pneumatic elevators. The air pressure difference between the upper and lower areas of the elevator cab is formed. This creates a vacuum, which uses air physics to convey the elevators. The elevator is powered by turbines or a vacuum pump that pushes it up and then releases pressure to allow it to descend. Pneumatic elevators are designed to be compact and are a suitable fit for residential elevators. Installing pneumatic elevators does not necessitate the use of a hoistway or an excavation hole.

2.2.5 Climbing Elevators

This sort of elevator is frequently found in construction and commercial settings. The majority of these elevators are powered by their own power source, which might be electric or combustion-based. Temporary climbing elevators are widely used in high-rise building construction to convey employees and materials before a permanent elevator is completed.

2.2.6 Industrial Elevator

- Incline Elevators

An inclined elevator is made up of one or two inclined tracks on a slope, each with a single payload car. In a two-track design, each car operates on the shuttle concept, moving up and down on its own track without regard for the other car. A car is either winched up to the station at the top of the incline, where the cable is gathered on a winch drum, or it is driven up to the station at the bottom of the incline. Alternatively, a car can be balanced by a counterweight travelling in the opposite direction along the track, similar to how an elevator works.

It can go up inclined grades, unlike a regular elevator. It is suitable for both home and business applications. The goal of inclined elevators is to allow users to access steep hillsides and inclines with little effort. A cable railway is a type of inclined elevator.

With their mobility scooter or motorized wheelchair, users with mobility and handicap problems frequently use an incline platform lift to climb stairwells in their homes. When stairs are not an option, outdoor inclined elevators are utilized to access steep hillside property. For industrial or construction applications, inclined elevators can also be utilized to transport equipment and commodities to difficult-to-reach elevated sites.

Within the European Union, inclined lifts are governed by EU lift rules part 22 EN 81-22:2014[5], which establishes some minimum requirements for their use: The track is incline between 15° and 75°; the maximum cabin capacity is 100 persons (7.500 kg); the maximum speed is 4 m/s; and the track is horizontally straight. These restrictions are not mandatory, and if an installation does not adhere to them—for example, if the path is curved—some unspecified further risk analysis is necessary.

3. ELEVATOR DRIVE SYSTEM TYPES

Think of the elevator drive as the brain, or more specifically a portion of the brain, of your elevator system. Its function is to operate the movements, speed, and torque of your elevator.

3.1 HYDRAULIC DRIVE SYSTEM

Lifting is a type of elevator that is powered by an electrically powered pump that sends hydraulic fluid to a lift that influences the cab directly or indirectly.

- The downward movement is carried out by the car's own weight in these elevators. The machine room is usually positioned at the first stop level in hydraulic elevators. The hydraulic fluid travels through an oil boiler and a hydraulic machine (control), control panel, and hoses.

- Inside the elevator shaft, there is a cabin, a counterweight if applicable, a cylinder piston system, a hanger assembly, and bumpers. The cylinder can be linked to the cabinet either directly or indirectly. The cabin is pushed to the necessary floor by the cylinder, and the control is taken.

- Hydraulic elevators are commonly found in apartments, villas, and houses, as well as in structures that are being repair. They are also employed in panoramic scenarios in industries and retail malls, where it is not desirable to add more load to the building's statics (eg renovation of antiquities).

3.2 ELECTRIC DRIVE SYSTEM

It should give a high level of comfort during car travel in electric-driven elevators, as well as accurate alignment at each stop. It should also be low-cost and low-cost (economic) to operate.

In low-rise structures, cabin speed is often less than 2.5 m/s. Elevators employ high-speed AC motors with worm screws as reducers to achieve these low speeds. In most cases, a 40:1 reduction ratio is employed. As a result, the design is tiny and compact, but the system efficiency is low.

Speeds of up to 2.0 m/s (such as 4 - 7 m/s) are surpassed in high-rise buildings such as skyscrapers and multi-store business centers. Low-speed DC motors are directly attached to the driving pulley in these elevators, and they are relatively costly designs.

3-phase voltage and constant frequency AC source is used for the drive of all elevators.. The voltage is controlled using the "power electronic pole control system," which connects AC motors directly to the mains. Alternating current is transformed to direct current in DC motors. For rotating machinery, the Ward-Leonard system with DC generator or the Thyristor-Leonard system is also utilized. Velocity-torque graphs are used to determine motor activities.

a) Ward-Leonard System

The Ward-Leonard mechanism is commonly utilized in rapid elevator DC drives. These systems feature excellent levels of safety and smooth speed regulation, but they are expensive to install and take up a lot of engine room space. In addition, the brushes on the high-speed generator and the commutator need to be maintained.

b) Thyristor-Leonard System

It is the suggested approach for eliminating the Ward-Leonrad system's drawbacks. The thyristor angle controls the average value of the DC voltage. The first and fourth quarters of the system are controlled by the first modifier; the second and third quadrants are controlled by the second modifier. When the current is reversed, these systems provide excellent dynamic braking.

3.2.1) AC Motors

Elevators frequently employ AC motors. AC motors, which have shown to be a cost-effective alternative, are utilized to power medium-speed elevators required for medium-rise structures. At cabin speeds of 0.6 to 1.6 m/s, a geared high-speed motor is used.

Single-speed motors are used in the majority of basic drives. Two-speed machines with brakes or acceleration and braking control are employed for a more pleasant drive. This is accomplished using voltage regulation or regulator power electronics equipment. Voltage and frequency regulated AC motors are still being developed.

a) AC Drive System Type with Single Speed and Reducer (Uncontrolled)

AC drives are used in many basic elevators. There is a synchronous motor that rotates at a single speed. The main supply is immediately supplied to high-speed geared machinery. The load torque TL and the acceleration torque TA are both dependent on the load, as seen in the acceleration-torque graph. As a result, the elevator travels unpredictably and has a propensity to bounce. A flywheel is put on the engine shaft to alleviate this issue. As a result, acceleration is decreased at full load. The brake is a double-shoe mechanical brake. There is no way to alter the braking torque. As a result, exact leveling may be impossible. This sort of drive is recommended when basic transportation comfort is desired and installation expenses are modest.

b) AC Drive with Double Speed and Reducer (Uncontrolled)

With two separate and distinct stator windings, two speeds may be achieved. Two rapid-moment graphs consist of two separate curves when using these devices. A single-speed AC motor has the same high-speed curve. Because it is an unregulated drive; the load determines the driving speed, duration, and distance. Splashing happens as a result of this. The braking torque is proportional to the load and rises as the load increases. Electrical braking is no longer available, and a mechanical brake is necessary to bring the cab to a complete stop.

c) AC Drive with Double Speed and Reducer (Controlled Braking)

DC current is used to regulate brakes in its most basic form. The eddy current is applied to the brake in this technique, and the synchronous speed is reset. This sort of application necessitates the usage of a regulated rectifier. Uncontrolled propulsion is equivalent to acceleration. As a parameter, fixed DC voltage values are used. As a result, the braking torque is managed. DC voltage changes with speed in practice, resulting in semi-constant braking torque when the speed is high. The braking torque is not specified at low speeds near to zero. Stopping precisely is a significant issue.

d) AC Drive with Double Speed and Reducer (Controled Braking and Acceleration)

Elevators' fast motion is controlled by power electronics. The single-speed motor windings' three-phase AC voltage is switched. The AC voltage fluctuates continually throughout acceleration, depending on the speed at which the semi-constant acceleration torque is generated. As a result, highly pleasant elevator driving is created when combined with regulated DC voltage at stationary.

e) AC Drive with Single Speed and Reducer, Without Reducer (Controlled Braking and Acceleration, Variable Voltage)

Induction machines with two independent stator windings are more expensive. The single-speed single-winding machine has been created with the best characteristics and is very cost-effective. For each phase sequence, single-speed induction motors have two combined voltage controls. This symmetrical performance, similar to the DC-Leonard drive system, allows for full 4-quarter functioning. The voltage is regulated based on the elevator's speed-time or speed-position profile. The fact that resistance losses grow with each acceleration, and notably with braking, is a disadvantage. It is dependent on the load moment, and in order to sustain these losses, a particular rotor design and a larger motor are required.

f) AC Drive with Single Speed and Reducer, Without Reducer (Controlled Braking and Acceleration, Variable Voltage and Frequency)

AC Drive with Single Speed and Reducer, Without Reducer (Controlled Braking and Acceleration, Variable Voltage and Frequency) The ideal AC drive for elevators must have voltage and frequency control.

High-speed gearless lifts and single-winding low-speed, low-frequency AC machines can benefit from this form of drive. The frequency converter is a significant investment. Cycloconverter AC drives and PWM* inverter AC drives are the two types of frequency changers.

3.2.2) Comparison of AC and DC Motor Used in Lift Drive

Elevator drive employs both DC and AC technology. DC drives are utilized in high-rise buildings (> 2.0 m / s) for high-speed rope elevators; AC drives are used in low-rise structures (2.0 m / s) for slower-speed elevators.

It provides maximum comfort and precision in elevator movement with minimal total losses because to its DC drive system structure. A changeable DC voltage source is, nevertheless, necessary. A Ward-Leonard or Thyristor-Leonard AC-DC converter is required. The DC drive is often directly linked to the source in many applications. Gearless drive motors are employed at pulley speeds of 100-300 rpm. The DC motor produces a lot of torque, but it's big, expensive, and requires regular maintenance. The AC drive is a simple and reliable induction machine. At extremely low pulley speeds, it is utilized in conjunction with a gearbox. The synchronous speed of frequency-driven AC equipment is constant. The AC drive's behavior can be improved and improved.

4. ELEVATOR DESIGN

In this project, our main mission is the design an elevator, so we need to make a block diagram, finalize the calculations, and to maket he simulation according to these calculations.

4.1 Problem Definition

We approached the problem in a diffrent way, we thought that, we can create more than one elevator design. But how? If we wont change some measurements for a basic motor, we can change other parameters such as (passenger load and pulley diameter) so, we can see how much torque do we need for different values.

4.2 Drive System Design Criteria

There are many variables which affect elevator system design. However the key ones to be specified are:

- Number of floors to be served
- Floor to floor distance
- Population of each floor
- Location of building
- Specialist services within building
- Type of occupancy
- Maximum peak demand in passengers per five minute period

To meet the elevator system specification, there are many design features which an elevator manufacturer can vary those are:

- Elevator speed
- Elevator car dimensions
- Load
- Number of elevators
- Elevator design characteristics

There are numerous parameters which can be used to judge elevator system performance. The principal one is based on quality of service. Quality of service is related fundamentally to the time interval a passenger has to wait for an elevator car and how quickly system transports that passenger to the desired floor, destination.

- *Quality of service* is the *expected average interval* (in seconds) between the arrival of elevators at the main floor
- In basic terms, this is *the round trip time* of one elevator divided by the number of elevator in a group
- The required *handling capacity* or quantity of service of a system is expressed in elevator industry design terms, as a function of expected building population.
- It is stated in units of the percentage of a building’s population to be transported within a five minute period

$$H = \frac{300 * Q * 100}{T * P}$$

- H: Handling capacity
- Q: Number of passengers
- T: Time interval
- P: Total number of population

$$T = \frac{RTT}{n}$$

- T: Time interval
- RTT: Round trip time
- n: Number of lifts

4.2.1 Effective Parameters in Electrical Drive of Elevators

Machine group	**Electrical state**	**Electrotechnical design**	**Mechanical design**	**Control type**	**Mechanical components**
Moment	Single-phase	Rotor type	Cast construction	Ward-Leonard	Gears
Speed interval	Tri-phase	Star/Triangle connection	Weld construction	Thyristor-Leonard	Brakes
Working conditions	Voltage	Single/multiple velocity	Rotor shaft material	Variable voltage	Generators
Load-moment characteristics	Frequency	Isolation	Surface treatment, paint	Variable frequency	Safety fuse
Moment of inertia	Current				
	Power factor				

Table 1. Effective Parameters in Electrical Drive of Elevators

Montage	**Environment**	**Base**	**Clutch**	**Cooling**
Montage method	Temperature	Dimensions	Belt and pulley	Weather
	Pressure	Weight	Coupling	Water
	Radiation	Terminal	Axial loads	Self cooling
	Water and dirty water	Oscillation conditions	Radial loads	Conditioning
	Noise			
	Height			

Table 2. Effective Parameters in Electrical Drive of Elevators

4.2.2 Geared Drive System and Gearless Drive System Comparisons

A good elevator should provide high capacity, comfortable, convenient and economical operation, acceleration and braking should not disturb the passengers, the electricity cost should be low and maintenance cost should be low.

Geared elevator motors are elevator motors with a gearbox connected to the motor shaft. Gearless elevator motors are the type of elevator motor where the drive pulley is directly connected to the motor shaft.

Considering that the energy efficiency of geared elevator motors is in the range of 55% to 75%, it can easily be seen that such motors are disadvantageous in terms of energy. Because of these limitations, the motor power must be selected 1.5–2 times larger than the required power, which requires the selection of other equipment related to the motor, which means an increase in the dimensions of the engine room.

In gearless machine motors, since the drive pulley is connected to the motor shaft, higher efficiency is obtained from such motors, so that larger loads can be transported with smaller motors.

The elevator engine room is usually the location of the elevator machine and its equipment, located above the elevator shaft. The machine room, which is an area determined according to the elevator speed and elevator load, should be moisture-free, well-lit and ventilated, with an ambient temperature of 5 to 40 degrees. Elevator machine rooms occupy a certain area in buildings and often do not conform to the aesthetics of the building. As gearless elevator motors eliminate the engine room, the installation is carried out in the elevator shaft, which is advantageous in high-rise buildings with heavy traffic.

To summarize the advantages of machine-roomless systems:

- Easy adaptation to any type of structure
- Optimum performance
- Quiet and comfortable cruise
- Excellent posture accuracy

• Aesthetics of building

• Less energy usage

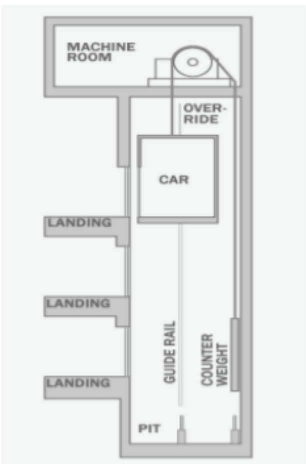
• Efficient and fast installation.

Another advantage of gearless machine motors is that they provide excellent ride comfort during starting, stopping and cruising compared to conventional geared machine motors.

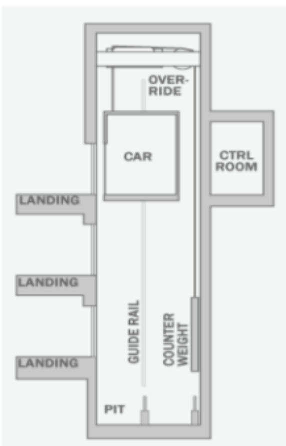
Gearless machine motors allow the elevator car to be perfectly aligned with the floor. Due to the soft take-offs and stops, the wear between the rope and the pulley is minimized, resulting in lower stripping than other machine engines. The absence of gears significantly reduces the need for maintenance and repair. Again, the absence of gear systems eliminates noise, vibration and oil problems and minimizes failures.

One of the most important advantages of gearless elevator motors is their energy saving. Due to the lack of gear systems, it is possible to select a motor with a power of up to half smaller than geared machine motor systems for the same travel speed and bearing capacity. The downsizing of the motor allows the other components of the equipment to shrink at the same rate.

Gearless machine motors have speeds up to 1.6 m / s, load capacities up to 2000 kg and can be used in structures up to 24 times. Gearless elevator motors are suitable alternatives for passenger terminals, multi-storey stores, shopping malls and health institutions.



(Figure 4.1- Elevator with Machine Room)



(Figure 4.2- Machine Roomless Elevator)

4.2.3 Elevator Drive System Starting, Speed Control and Breaking Method

Starting Method (Direct Online or Star-Delta Methods)

When space for the panel is available, elevator systems can be readily controlled by a PLC program. To start the drive motor, one of the Star-Triangle or Direct-Online starting methods might be used.

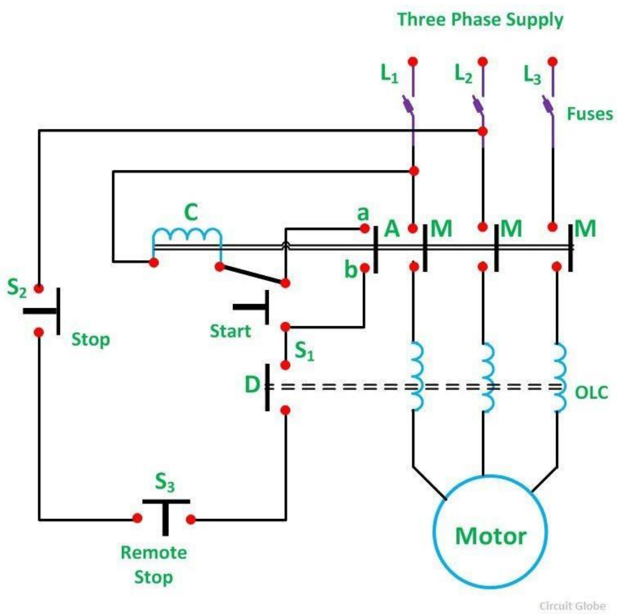


Figure 4.3-Direct-Online Starting 3-Phase Induction Motor

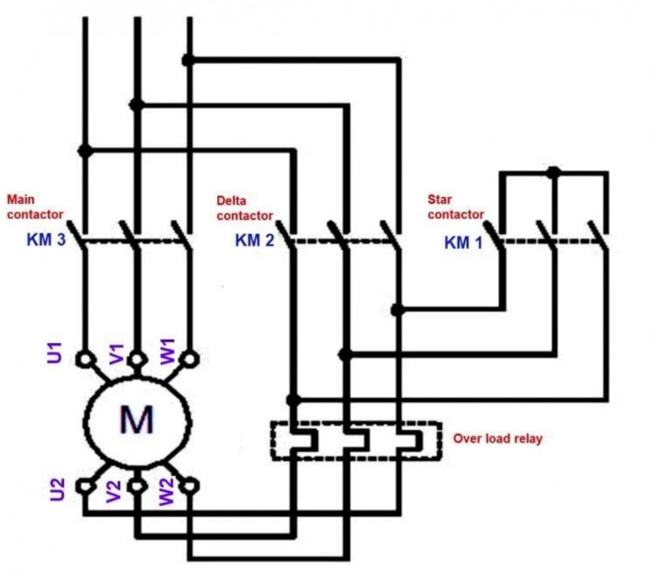


Figure 4.4- Y-Δ Starting Circuit

Method of Speed Control (Variable Voltage Variable Frequency)

• The number of poles and frequency are proportional to the speed of induction motors.

• As the frequency rises, so does the speed. The speed is reduced when the frequency is reduced.

• However, when the frequency changes, so does the motor current.

• As the frequency drops, the motor current rises, causing the motor to overheat and burn. As the current flows and the motor torque diminishes, the reverse frequency rises.

•The frequency and voltage are altered jointly in this scenario to keep the motor current constant.

V / F or VVVF (variable voltage / variable frequency) is the name of this approach.

Figure 4.5 -VVVF Controller model EOM LX-3000

Breaking Method (Regenerative Breaking)

- Regenerative braking energy created during the braking phase of the elevator motor

(a) storage in ultra-capacitors and re-use of stored energy in the elevator's energy demand

(b) The AFE (active front-end) drive unit, which facilitates bi-directional energy flow, recovers the regenerative braking energy as utility energy and sends it to the grid.

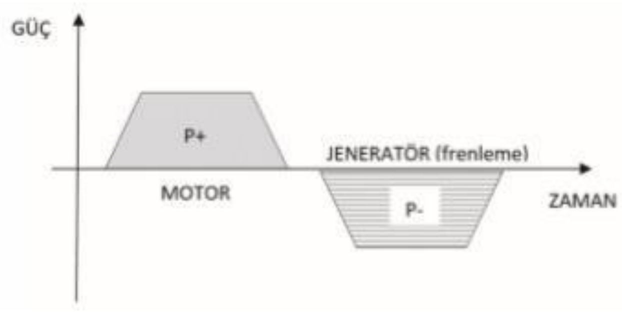


Figure 4.6 - Motor and generator operating zones in the elevator operating cycle

Brake energy is consumed as heat in the braking resistor in conventional elevators because the elevator motor drives employ diode rectifiers that do not allow free flow of energy in both directions. This results in significant energy loss. It is possible to return regenerative braking energy to the grid with elevator drive systems that use a fully controlled IGBT inverter instead of a diode rectifier.

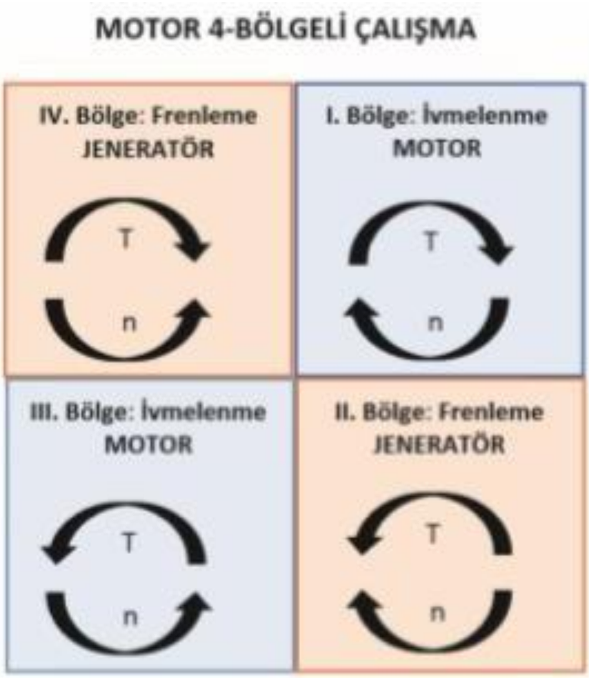


Figure 4.7 -Quadrant operating phases of AC motor T=Torque n=nominal

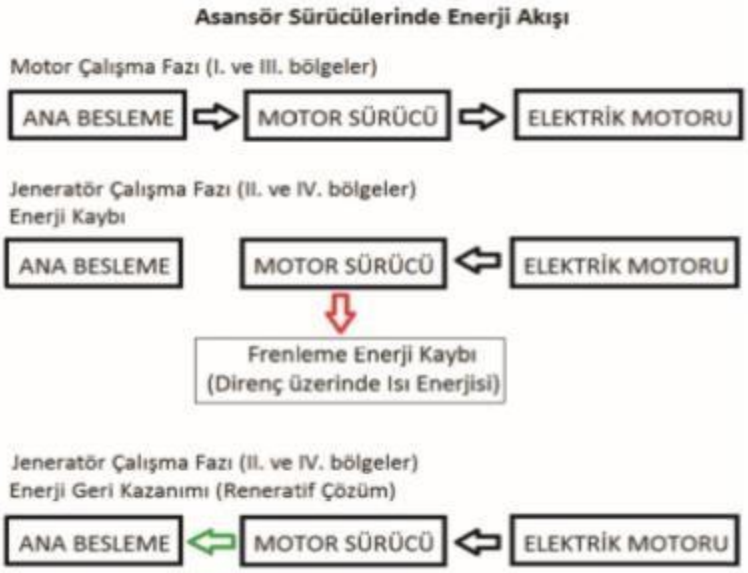


Figure 4.8- Energy flow in elevator drives: motor operating zones (zones I and III) and generator operating zones (zones II and IV)

The reverse energy flow can occur in two ways during the generator's operational period.
a-) braking energy is consumed as heat energy on the resistor
b-) via a regenerative unit, back to the network
The AC drive can function as a motor or a generator, depending on the car's load and movement. The electrical energy is extracted from the grid during the motor phase, and the generated regenerative braking energy is sent back onto the drive's DC connection during the motor braking phase.

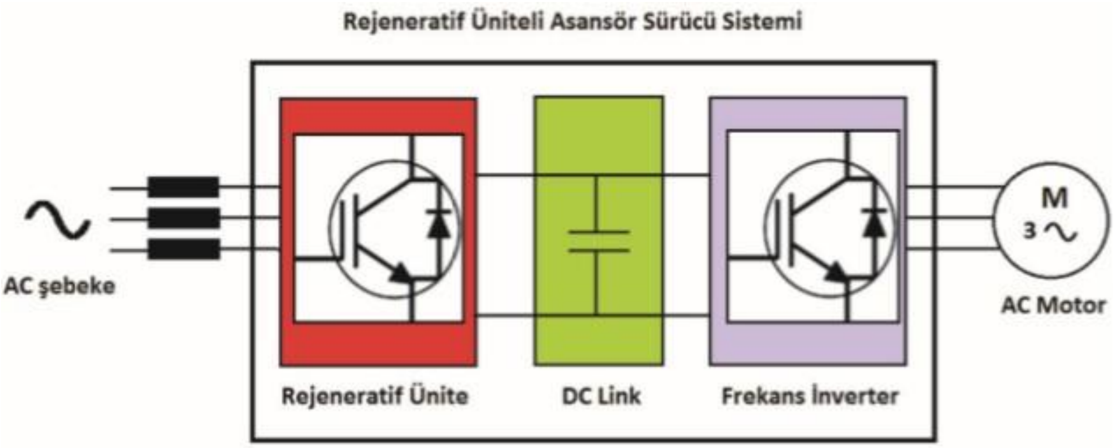


Figure 4.9 The main components of elevator drive system with regenerative unit

The regenerative unit in the motor phase acts as a rectifier to provide energy flow from the AC network to the motor, while the motor braking phase acts as an inverter to ensure that the regenerative braking energy generated in the motor flows from the DC link to the AC grid in the bidirectional regenerative elevator drive design proposed in the figure.

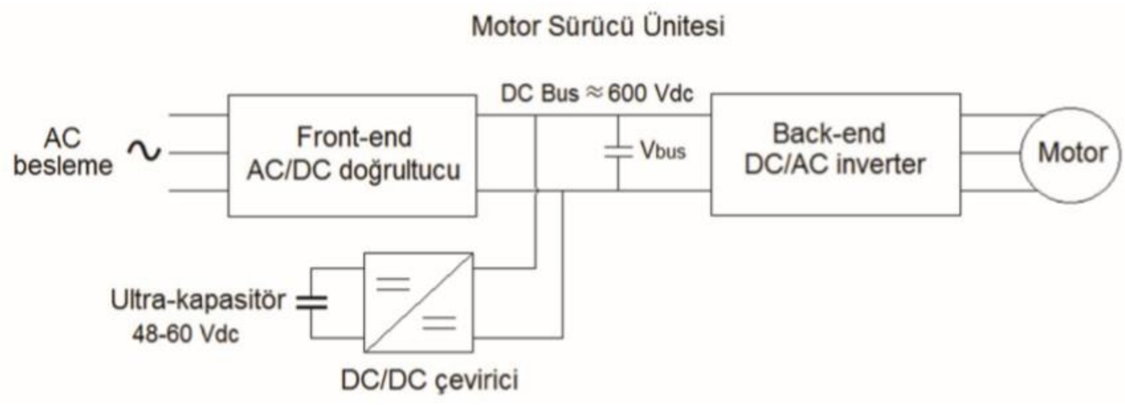


Figure 4.10 Recommended ultra-capacitor power storage unit supported drive design for regenerative braking energy recovery.

4.3 Design Calculations

Desıgn Crıterıa:

- 8 floors for buildings
- Maximum capacity = 8 passenger
- $m_{pssngr,max}$ = 630 kg

We need to use standards to determine the weight of the empty cabin.

İnsan Sayısı	Kabin Yükü	Kabin ağılığı	İnsan Sayısı	Kabin Yükü	Kabin ağılığı
2	160	250 350	10	800	800 1200
4	315	400 600	16	1250	1000 1600
6	450	550 800	21	1600	1500 2000
8	630	700 1000	33	2500	2000 4000

Table 3.-Elevator design standarts table

- m_{cage}= 700 kg

Tablo 3. Kabin hızları

Bina Tipi	Kat Adedi	Hız [m/s]	Bina Tipi	Kat Adedi	Hız [m/s]
Konut	≤ 8	≥ 0.63	Otel	≤ 6	≥ 1
	> 8	> 1.0		≤ 10	1.2 - 1.5
	≥ 12	1.2 - 1.5		≤ 15	2.0
	≥ 16	2.0		≤ 20	2.5
	≥ 20	≤ 2.5		≥ 20	≤ 3.0
Büro ve İş Merkezi	≤ 5	≥ 1			
	≤ 10	1.2 - 1.5			
	≤ 15	2.0			
	≤ 20	2.5			
	≥ 20	≤ 3.0			

Table 4.- Elevator design standarts table

So we choose 1 m/s due to recommendation.

- v_{cage}=**1m/s**

Now we will determine our motor;

GEM LION LİFT MACHİNE MOTOR

Teknik Özellikler	
Dingil - Yavaş ve hızlı miller arasındaki mesafe	140 mm
Maksimum Statik Yük	3.100 Kg (Dış destek olmadan)
Maksimum Tork Çıkışı	1.425 Nm
İndirgeme Oranı	1/58 – 1/53 – 1/44 – 2/70
Maksimum Motor Gücü	6.8 KWasy (50 Hz - AC2) - 7.6 KWasy (50 Hz - VVVF)
Motor Tipi	AC1, AC2, ACVV, VVVF
Ortalama Dişli Verimliliği	0.75
Kasnak Çekme Çapı	480 mm, 560 mm, 600 mm
Elektromanyetik Fren	24V, 48V, 60V, 110V, 200V
Sentetik Yağ	3,5 LT (Ömür boyu yağlı)
Makinenin Ortalama Ağırlığı	260 Kg

Table 5- Motor's technical property's

Örnek Hız ve Yük Tablosu (50 hz - 1500 rpm)

Taşıma Kapasitesi (Kg)	Hız (m/sn)	İndirgeme Oranı	Kasnak Çapı (mm)	Motor Gücü AC2 (KWasy)	Motor Gücü VVVF (KWasy)
630	0.71	53/1	480	5.1 <7.5 Hp>	5.1 <7.3 Hp>
630	0.83	53/1	560	5.5 <8.1 Hp>	5.5 <7.8 Hp>
630	1.00	44/1	560	6.8 <10.1 Hp>	6.8 <9.7 Hp>
630	1.07	44/1	600	6.8 <10.1 Hp>	6.8 <9.7 Hp>
630	1.01	70/2	560		7.6 <11.0 Hp>

Table 6- Motor's technical property's

D=600mm//*diameter*

u=44/1//*ReductionRatio*

Efficiency=0.75

Full Cage is Lifting Condition = Empty Cage is Lowering Condition

$$m_{passenger} + m_{cage} - m_{cw} = m_{cw} - m_{cage}$$

$$m_{cw} = \frac{m_{passenger}}{2} + m_{cage}$$

$$m_{cw} = \frac{630}{2}$$

$$m_r = m_{passenger} + m_{cage} - m_{cw} = \frac{630}{2} = 315\text{kg}$$

$$T_{m1} = \frac{m_r * g * D}{2 * u * efficiency} = \frac{315 * 9{,}81 * 0.56}{2 * 44 * 0.75} = 26.22 N.m$$

Full Cage is Lowering Condition=Empty Cage is Lifting Condition

$$T_{m2} = \frac{m_r * g * D * efficiency}{2 * u} = \frac{315 * 9.81 * 0.56 * 0.75}{2 * 44} = 14.75 N.m$$

$$w_l = \frac{v}{\frac{D}{2}} = \frac{1000\frac{mm}{s}}{280mm} = 3.57 rad/s$$

$$w_m = w_l * u * efficiency = 3.57 * 44 * 0.75 = 117.81\text{rad/s}$$

(without efficiency factor $w_m = 1500$)

$$n_r = \frac{60 * w_m}{2 * pi} = 1125 rpm$$

$$n_s = \frac{120 * fs}{pole\ number} = \frac{120 * 50}{4} = 1500 rpm > 1125 rpm$$

$$\text{Slip}=\frac{n_s-n_r}{n_s}=1-\frac{1125}{1500}=0.25Hz$$

$$Dissipated\ power=T_{m1}*w_m=26.22*117.81=3.089kW\ <7.5kW$$

$$w_m=w_l*u\ \rightarrow\ \ 3.57*44=157.08$$

4.4 Design Outputs

```
%% electrical driving report

clear all;
close all;
clc;

% variables

m_passenger = [500:50:1500]';
m_cage = 630;
m_cw = 945;

g = 9.81;
D = [0.26:0.1:0.56];
u = 44;
efficiency = 0.75;
v = 1000;
f_s = 50;
pole_number = 4;

%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
%% calculations

% total mass
m_r = m_passenger + m_cage - m_cw;

torque_m1 = (m_r.*g.*D)./(2.*u.*efficiency);
torque_m2 = (m_r.*g.*D.*efficiency)./(2.*u);

w_l = v./(1000.*D./2);
```

```
w_m = w_l.*u.*efficiency;

n_r = 60.*w_m./(2.*pi);

n_s = 120.*f_s./pole_number;

slip = (n_s - n_r)./(n_s);

f_r = f_s.*slip;

dissipated_power = torque_m1.*w_m;

%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
%% figures

figure
plot3(torque_m1,torque_m2,m_passenger)
grid on
xlabel('Torque_{m1}')
ylabel('Torque_{m2}')
zlabel('Passenger Mass')
title('Required Torque Value for Passenger Mass')
legend('D : 0.26','D : 0.36','D : 0.46','D : 0.56')

figure
plot3(w_l,w_m,D)
grid on
xlabel('w_{l}')
ylabel('w_{m}')
zlabel('Diameter')
title('Required Velocity for Diameter')

figure
plot(m_passenger,dissipated_power)
grid on
hold on
plot(m_passenger,6800*ones(length(m_passenger),1))
xlabel('Passenger Mass')
```

```
ylabel('Dissipated Power')
legend('Dissipated Power','Critical Region')
title('Dissipated Power Region')
```

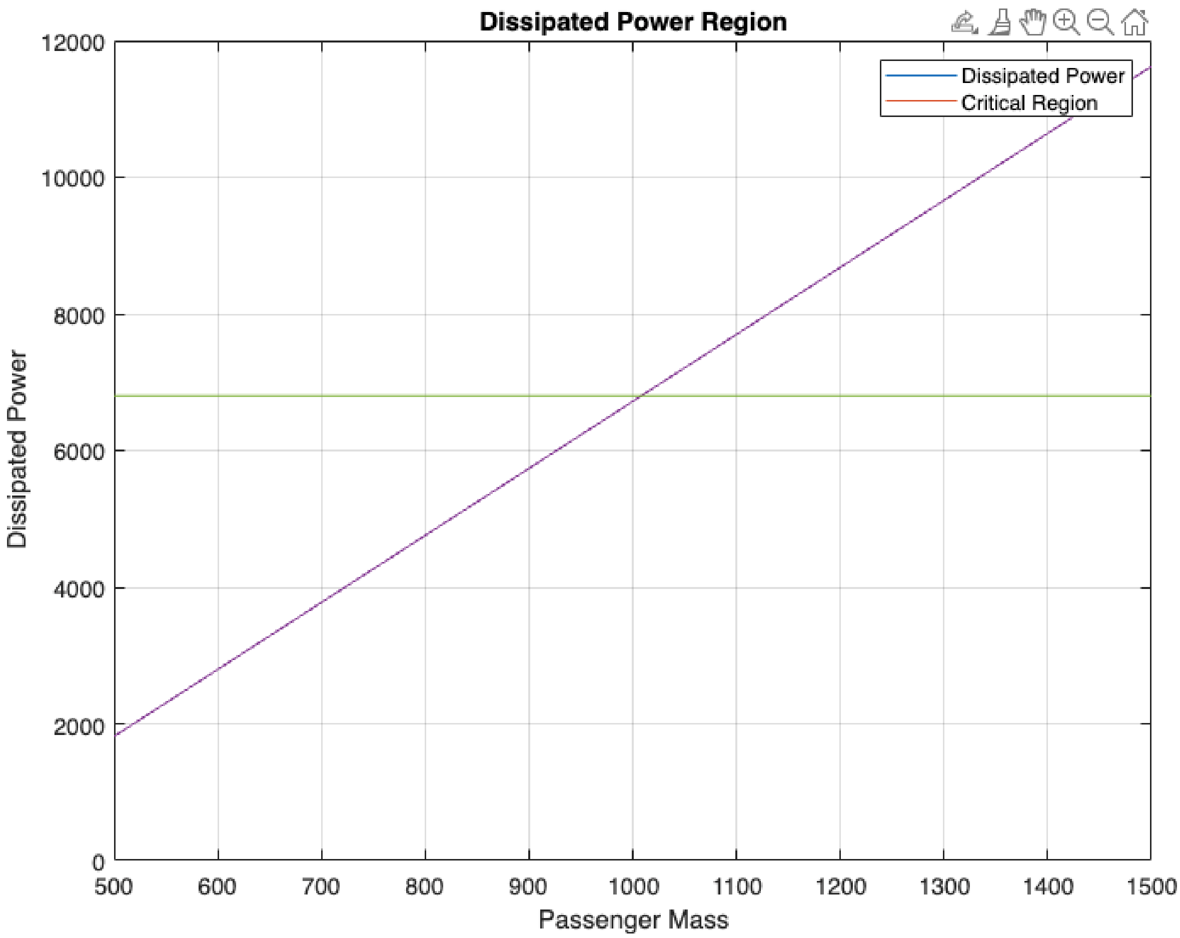


Figure 4.11 – Dissipated Power Region Graphic

In this figure, we calculated, how many kilograms we can use for our desing, less than 6800W power. According to graph, we can design an elevator which can lift maximum 1000 kg.

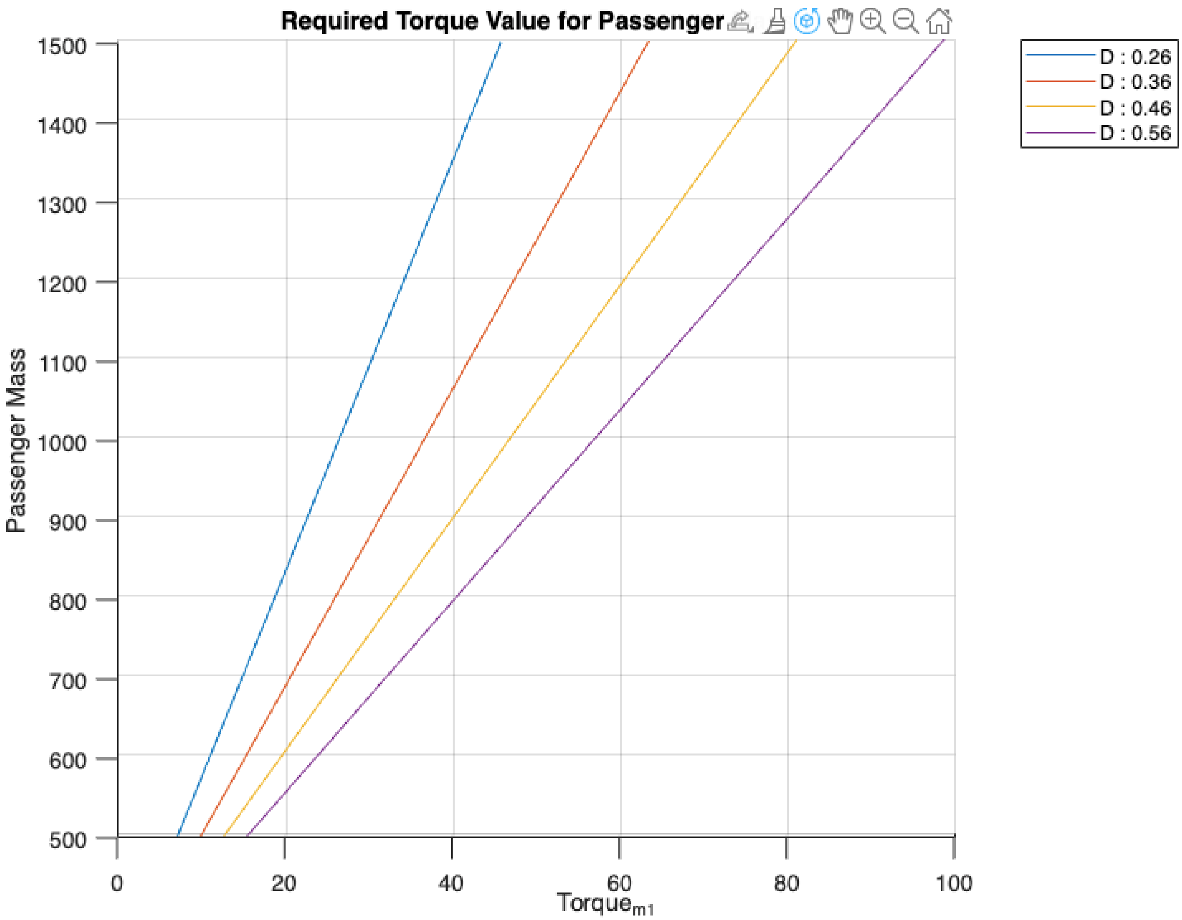


Figure 4.12 Required Velocity for Diameter for m_1

In this graph, we can see that, our torque value T_{m1} increases if we choose higher pulley diameter and high passenger mass.

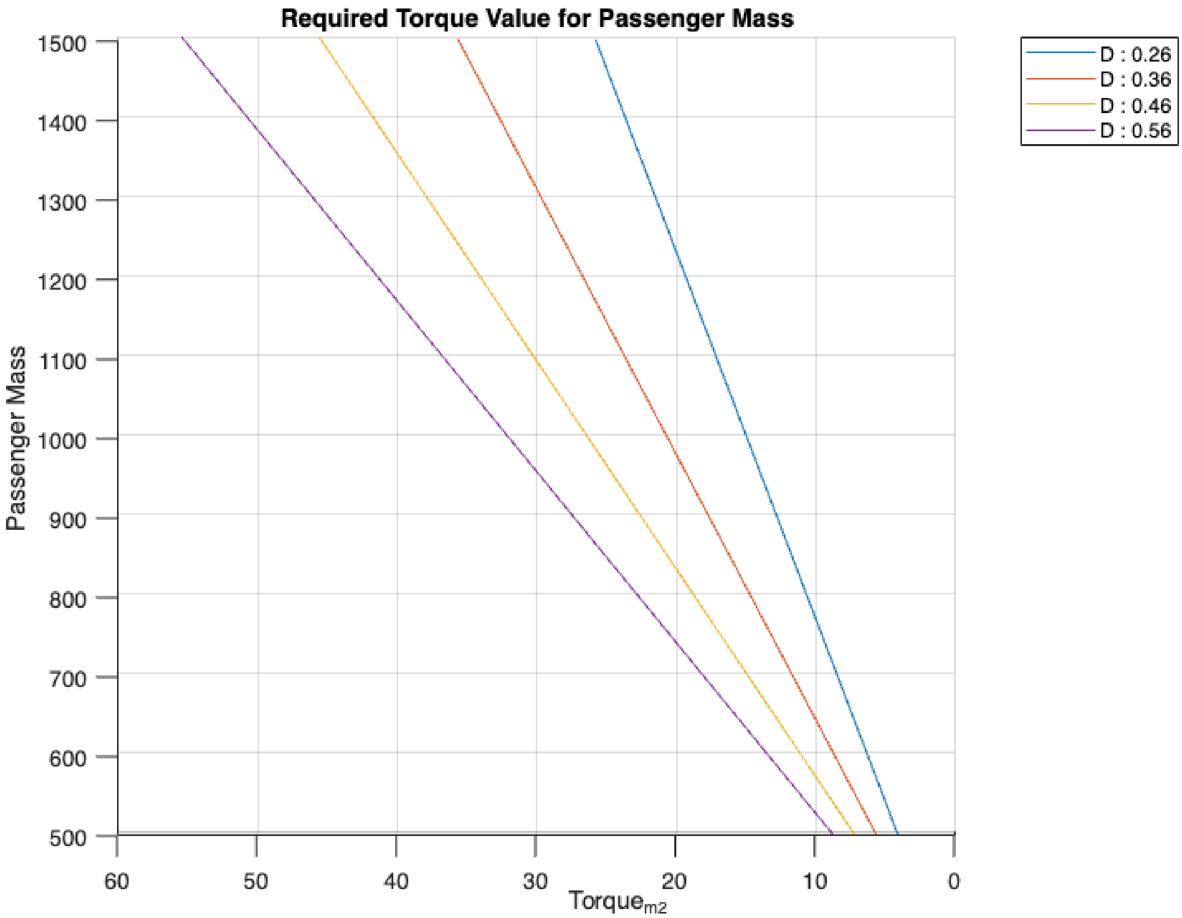


Figure 4.13 Required Velocity for Diameter for m_2

In this graph, we can see that, our torque value T_{m2} increases if we choose higher pulley diameter and high passenger mass as same as the previous graph.

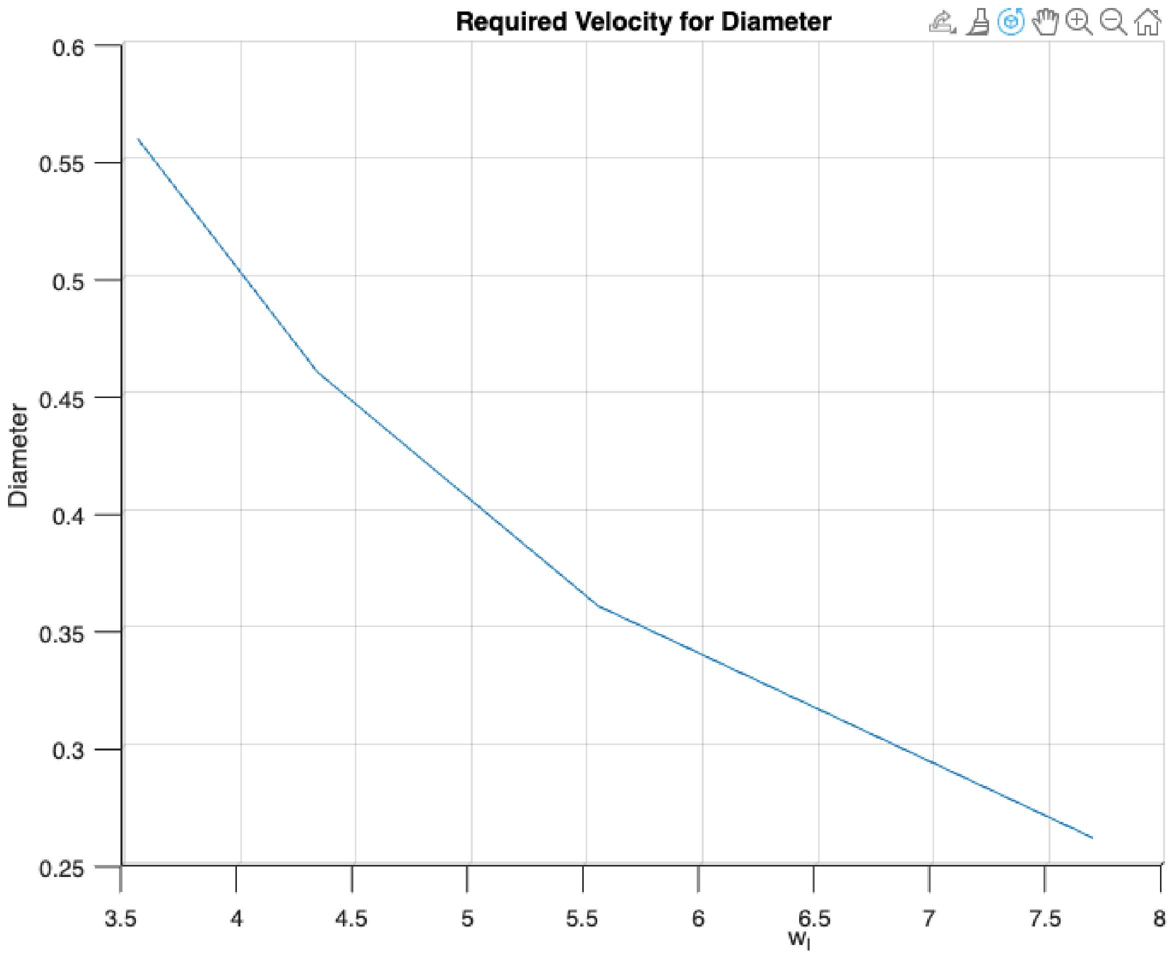


Figure 4.14 Required Velocity for Diameter for w_l

In this figure, we calculated angular velocity with pulley diameter. We can see that, while the diameter goes higher, angular velocity (w_l) goes lower.

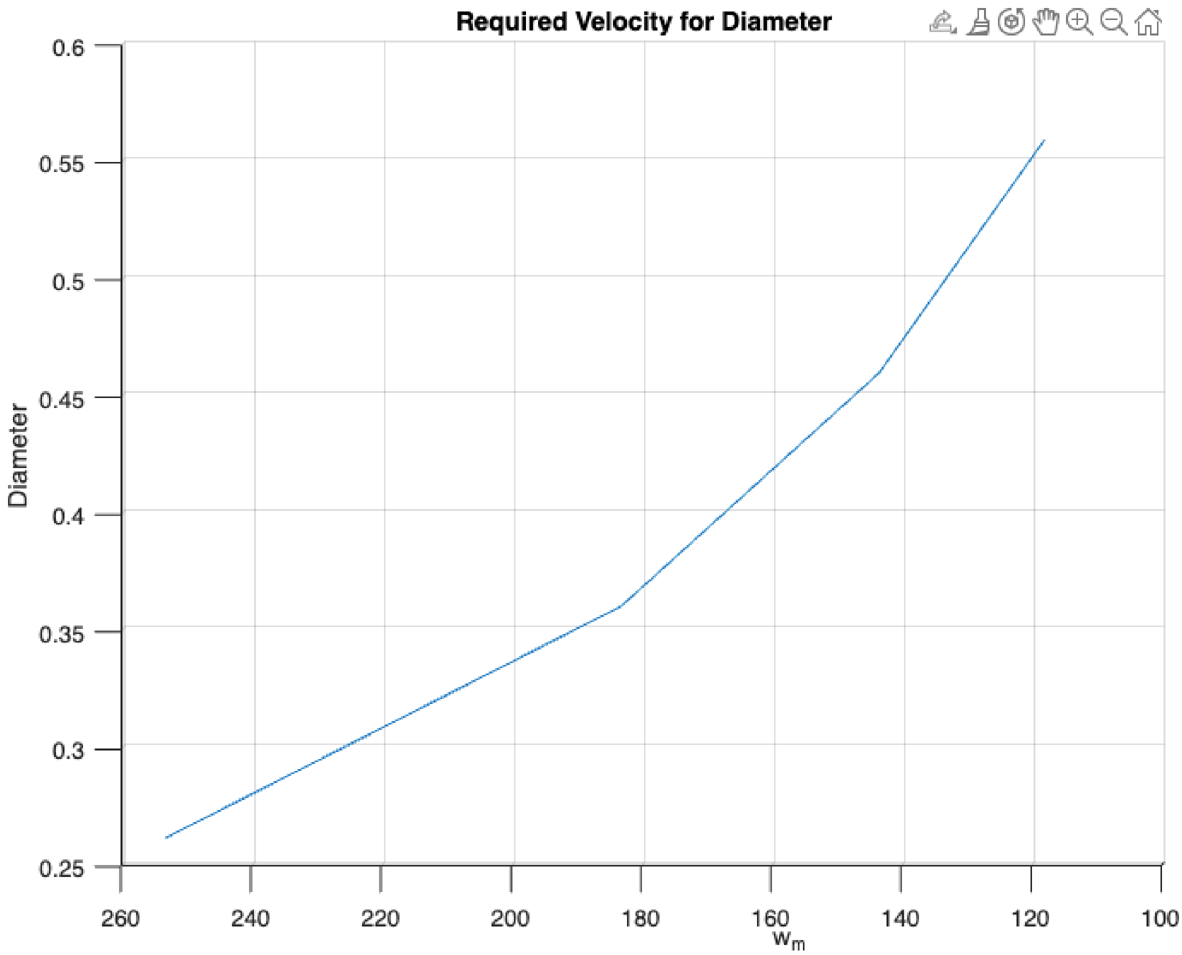


Figure 4.15 Required Velocity for Diameter for w_m

In this figure, we calculated angular velocity with pulley diameter. We can see that, while the diameter goes higher, angular velocity (w_m) goes lower as same as the previous figure.

To conclude all of these graphs, we can say that if we want to design an elevator which can lift high passenger mass, we should choose a motor that has low torque value but the elevator speed will be low. If we want to design a faster elevator than we should choose lower pulley diameter.

5. CONCLUSION AND FUTURE WORK

In the future, we think that, there can be a general solution when we need to design an elevator. We only change pulley diameter and passenger load to finish our calculations. If we extend this work, we can add some other parameters inside the motor for motor selection. What can be other parameters? We can design some other simulations for changing efficiency.

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