Design of Safety System for a Solar Powered Passenger Elevator

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Abstract**—** *The proliferation of science and technology has reduced human efforts in every field. Many of the human activities now rely on technological innovations. The past two centuries have seen a phenomenal improvement in various inventions and discoveries. Same is the case with the first elevator which finds mention in ancient texts to its development in last two centuries. The first commercial passenger elevator was installed by the Otis Elevator Company in 1857 in New York City. It climbed at a then-staggering rate of 40 feet per minute [1].Today, an Otis elevator in the Burj Khalifa tower in Dubai soars up at a speed of 22 mph [1]. The development in the lift and elevation technology is commendable. One step in the research work in elevation technology is undertaken here in which a hydraulic safety system for a solar powered lift is designed for the case of emergencies, rope breakage and power failure and safely brings the lift to the ground floor in any case of emergency. This lift working on solar power is used to move passengers and other things from one level to another. After the designing of the lift safety system and working analysis of the lift system, the results show that it saves floor space due to its compact and small but sufficient design and saves energy as it does not use any external source of energy.*

Keywords— Solar Elevator, Solar Powered Passenger Elevator

I. INTRODUCTION

An elevator or lift is a type of vertical transportation that moves people or goods between floors (levels, decks) of a building, vessel, or other structure. Elevators are generally powered by electric motors that either drive traction cables or counterweight systems like a hoist, or pump hydraulic fluid to raise a cylindrical piston like a jack [2].

As we know that the most efficient use of the available resources of energy is the need of the hour. So we need to apply minimum output, obtain maximum output and save as much energy as possible. As solar energy is free, readily available, and renewable and yields no pollution, it can easily be used to obtain the driving electricity for an elevator. The solar power elevator uses the electricity created by the solar energy with the help of photovoltaic or solar panels. A solar cell, or photovoltaic cell (PV), is a device that converts light into electric current using the photovoltaic effect [4]. Solar panels are placed on the rooftop of the building to create the power for the elevator. The energy that is captured by the solar panels can be used immediately, stored in batteries, or even re-sold to the grid. Having the stored energy will make travelling in one of the solar powered elevators safer. It offers a unique advantage of having stored power during a power outage. This will allow a building to tap into the stored solar energy to continue operation, minimizing the chance of an elevator getting stuck in the shaft.

So during the day time when the sunlight is incident on the solar panels then due to the photovoltaic effect of the photovoltaic cells, the electricity is produced. This electricity can be directly used or can be stored in batteries by energy recovery systems. This produced electricity is used to drive the motor and the sheave of the elevator which moves the elevator from one floor to another.

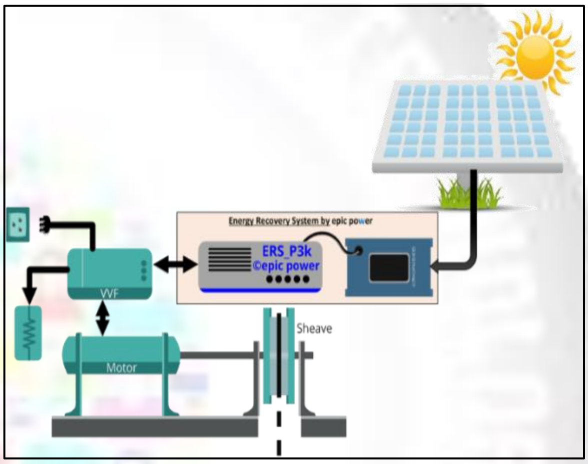

Fig. 1: Electricity production for solar elevator [6]

II. PRINCIPLE

In the case of emergencies like fire, earthquake or power failure, the lift may get stuck in the lift shaft. Or during emergency like lift rope breakage, the lift will be free falling towards the ground level at a very high velocity which results to a high impact collision of the lift car with the ground causing destruction of the carried goods, severe injury and even death of the passengers. To avoid such accidents, the lift is installed with a safety system that ensures the safe working of the lift. This system consists of various progressive safety gears, over speed governors, spring and oil buffers, etc. that absorb the impact and kinetic energy of the falling lift and minimize the amount of damage caused to the accident or the possibility of lift stuck.

In the undertaken research work, we will design a hydraulic safety system for the elevator which will use fluid energy for the safe operation of the lift. This system will be capable of making the elevator return back to the ground level in any case of emergency like power failure, earthquake, fire, rope breakage, etc. with least or no loss. This hydraulic safety system will comprise of various components like a cylinder, piston, connecting rod, hydraulic fluid pipes, valves, bolts and C-joints. The design of this system is presented here.

III. DESIGN AND CALCULATIONS

Component	Specification
Lift Cage Dimensions	30”x45”
Height	84”
Space to design safety component	5”
Guide ways width	2.56”
Distance between two guide ways	26”
Motor Capacity	0.5 HP, Single Phase
Maximum no. of passenger	4
Number of ropes	1
Method of operation for elevation	‘Press to ON’ Switch
Travel Up time	45 sec
Travel Down time	40 sec
Cage wall cover	Fiber resin polymer
Frame \ Chassis	2”x2”x4mm square MS pipe
Guide rollers	12
Tracking rail angle	75mmx75mmx75mm
Cabin	24mmx24mmx3mm, SS304
Pulley	4, 6”Dia with Z type bearing
Cable Winding drum	6” dia and 5” width
Landing spring	10”, Compression Weight 200 kg, Solid length 4”.

Table 1: Lift specifications

The lift under consideration in this project has eight solar panels each of 75 watt which generate 2.4 KWh per day. That means we can use the lift for 6 hours continuously.

The actual operational period for the given lift is 1 hour / day or 30 to 35 operations to and fro. Hence the given lift can be used for 5 days in case of a power failure.

Fig. 2: The subject lift

A. *Design consideration for Hydraulic Safety system*

When the lift moves upwards: As the lift moves upwards the piston inside the hydraulic cylinder to be designed will move in upward direction. This will lead to vacuum being generated in the bottom part of the cylinder. So oil will pass from upper portion of the cylinder to the lower via the C-pipe connecting the two halves of the cylinder.

When the lift moves downwards: As the lift descends the piston inside the hydraulic cylinder to be designed will move downwards. Hence the oil will flow from bottom of the cylinder to the upper part via flow regulatory valve in the second C-pipe in such a way that mass flow rate of oil is maintained. This will enable the lift to reach the ground floor in 35 seconds without consuming any energy.

Parts	Numbers	Function
C - Joint	1	Connects elevator chassis and connecting rod
M14 Bolts	4	Fastens the channel with chassis
Cylinder	1	Guide the piston & provide control volume
Piston	1	Transmit force
Hydraulic Pipe	2	Connect the reservoir and cylinder; Provide path to oil flow
Non return valve	1	Allow one direction flow of the oil
Connecting Rod	1	Connects the piston and channel

Table 2: Safety Mechanism Components

Here is schematic diagram of the system to be designed.

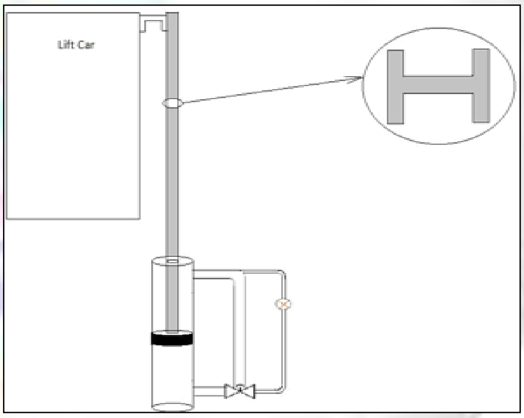

Fig. 5: Schematic diagram of hydraulic safety system

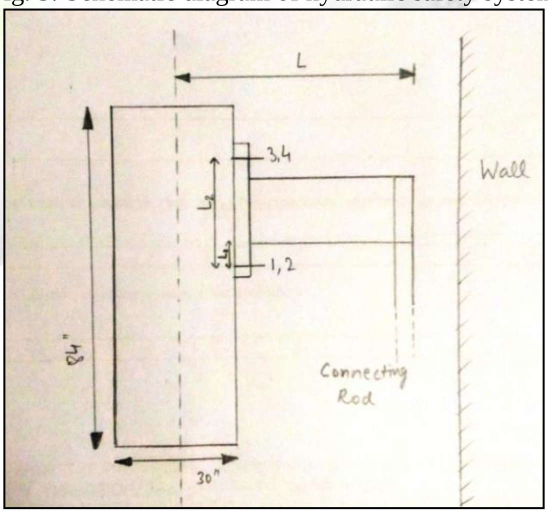

Fig. 6: Space available to design C- Joint

Symbol	Definition	Value
W	Total load	5000 N
L	Distance between load & bolt	609 mm
L_1	Distance between bolt & lower edge	10 mm
L_2	Distance between bolt & upper edge	40 mm
W_S	Shear load on each bolt	1250 N
N	Number of bolts	4
W_T	Tensile load carried by bolt	35820 N
σ_T	Allowable tensile strength of bolt	84 MPa
D	Diameter of cylinder	80 mm
A	Cross sectional area of cylinder	5026.5mm^2
Σ	Allowable stress	82 MPa
T	Shear strength of piston	81.5 MPa
E	Modulus of Elasticity	210GPa
L_c	Length of connecting rod	3657.6 mm

Table 3: Data for Designing components

The C-joint requires 4 bolts. The calculation for the same is done using the following data and equations,

B. Design of C- Joint

This data is used in the following equations and the bolt dimensions are calculated [3].

$$W_{Teq} = 0.5*[W_T + \sqrt{W_T^2} + \sqrt{4W_S^2}] \quad (1)$$

$$W_{Teq} = (\pi/4 * d_c^2\, \sigma_T * n) \quad (2)$$

$$d = d_c/0.84 \quad (3)$$

Symbol	Definition	Value
W_{Teq}	Equivalent load	35863.5 N
d_c	Core diameter of bolt	11.657 mm
d	Bolt diameter	13.877 mm

Table 4: Designed Dimension for C-joint bolts

So, M14 Bolts should be used and the design is safe.

C. Design of Cylinder

Design of cylinder includes the determination of diameter and thickness of cylinder. Diameter of cylinder is arbitrarily determined according to the space between wall and lift.

For the calculation of thickness the pressure developed inside the cylinder should be computed [3].

$$P = (W/A) \quad (4)$$

So, P=0.9925 MPa or 1 MPa

$$t = (PD)/(2\sigma) \quad (5)$$

So, t=0.4878 mm

Pressure in cylinder is 1MPa and thickness of cylinder wall is 0.48mm.

D. Design of Piston

It includes determination of diameter and thickness of piston [3].

D_P=Dia. Of piston (same as cylinder) = 80 mm

T_p= Thickness of piston

$$T_p = W / (\pi * \tau * D_P) \quad (6)$$

T_p= 0.244 mm

E. Design of Connecting Rod

It includes the design of flanges and sections of the connecting rod section [3]. Let t = thickness of flange

B = 3t = width of flange
H = 4t = depth of section
Area A= 8t^2
Moment of inertia I_{XX}= (176/12) * t^4

Allowable stress in the section should not exceed 280 Mpa.

$$\frac{W}{A} + \frac{M_y}{I_{XX}} = 280 \quad (7)$$

i.e. 280t^3 – 625t -415636.36 = 0
So, t=11.47mm or 12mm
Hence, B=36mm, H=48mm
I_{XX}=304128 mm^4
Now checking design for long beam,

$$\text{Critical load } P_c = \frac{2\pi^2 E I_{XX}}{L_c^2} \quad (8)$$

Pc=94.23 kN >> 5 kN. So, Design is safe.

F. Design of Pipes

For design of pipe-1, our aim is to find its diameter and thickness which will serve its purpose. Now, we know that the diameter of piston is 80mm. Since lift travels 11 ft in 40 seconds so its velocity is 11ft/40s i.e. 0.08382 m/s. Length of cylinder pipe is 11.5 ft. And velocity at which piston is coming downwards is known to be 0.08382 m/10s.

So, the flow rate 'Q' of the fluid in the piston cylinder will be given by the formula [5],

$$Q = A_P * V \quad (9)$$

Q= (0.25*0.08*0.08*0.08382) = 0.00042111168 m^3/s.

For the hydraulic safety system, the pipe of diameter 20mm with the thickness of 0.1mm is taken as it is suitable for the safety system pipes [7].

Based on the requirements of the system, with the help of the following graph ISO grade 32 oil is selected.

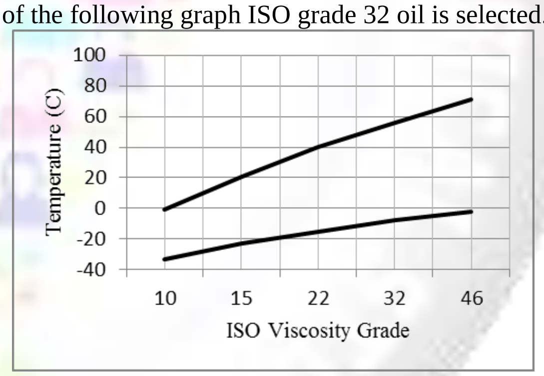

Fig. 7: Property variation of ISOGrade32 oil & temperature [8]

IV. Result

All the components of the hydraulic safety system is designed. The design is safe and within the limits to avoid most probable types of failures. Using these components the hydraulic safety systems for the solar powered elevator is constructed. The stress analysis of the above model can be done by design softwares available. Further after getting its results actual manufacturing of the above design model could be done.

V. Conclusion

As observed, when the rope fails, the given lift comes down by its own without any stoppage and lift blockage using the hydraulic energy. While in working condition, it is being run by a single phase motor. So by doing modifications in the motor, more power saving can be done by using hydraulic system to drive the lift while descending and ascending.

Thus, this system is a reliable safety system which is independent of the electrical power supply. It only depends upon the solar energy. As the conventional elevator systems and the conventional safety systems run only upon the direct electricity sources, so these have a high possibility of failure during power shortages, rope breakages and power failures. Hydraulic safety system saves the electricity and is a viable replacement of present safety system.

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