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Alternate Energy : Gravity Powered Rail Transportation Systems

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Abstract

A simple pendulum shows how efficient gravity is in recovering energy. Any transportation is a linearly oscillating system; every load gains kinetic energy, but loses the same to come to a stop. The Gravity Power Towers comprise of a set of vertically moving heavy masses coupled, through microprocessor controlled continuously variable gear and cable system, to a horizontally rolling unit on wheels either on rail or road. The heavy masses move vertically up against gravity gaining potential energy while stopping a moving mass; move down under gravity force, giving out energy. The Tower thus accelerates or sustains the speed a rolling unit, and while decelerating, recover the kinetic energy. Speeds of 360 kmph can be attained. Recovery of energy varies from 98.5-70%; the longer the distance between stops, the lesser is recovery. The economical, omnipresent & eternal Gravity Power grants energy independence to many a nation. Global warming reduces.

Keywords : *Gravity power, Rail transportation, Global warming, 360 kmph, Potential energy, Kinetic energy, Gravity power tower, Pendulum, Energy, global warming*

1. Introduction

Gravity, the fourth fundamental force so prevalent, remained an enigma and treated more as a force to be resisted and managed on the planet. Fossil fuels and electromagnetic energy are our current choices. If we are able to harness omnipresent gravity force for our needs in a proactive manner, a new chapter opens for human civilization improving quality of environment reducing carbon emissions as well as provide an unlimited free source of energy.

We do consume substantial quantum of energy in transportation. Maximum rate of work is observed during accelerating a mass from rest to a cruising speed. Power needs are quite high in this phase. Every mass rolling at a speed finally has to be brought to halt, and most of the time the kinetic energy is wasted as heat in braking the rolling mass to a halt. Efforts for regeneration in electrical driven systems using asynchronous motors yielded partially successful results in energy recovery limited to less than 20 to 30%; which also involves substantial capital intensive infrastructure.

The recovery of energy in pendulum is remarkable. The potential energy is converted into kinetic energy and back to potential energy with remarkable efficiency in this oscillating system. Recognizing the linearly oscillating system formed by transportation of masses, in this paper a means is described to convert potential energy of masses with capability of moving up and down, into kinetic energy of horizontally rolling mass, and then convert back the kinetic energy in to potential energy of the vertically moving mass, thus recovering most of the energy, except for loss of energy in hysteresis. Gravity becomes the prime mover in transportation, which can redefine quality of our life on the planet.

2. The Principle

Let M be the mass as in Fig. 1 which is at a position h1 at time t1 and connected through a gear and cable system having a gear ratio of 1:n, to mass "m" on wheels rolling in a generally horizontal direction, which is same as perpendicular to the direction of motion of mass M; n being the gear ratio at time t1 such that mass "m" moves n1 times what the M moves vertically. This can be represented by the relationship:

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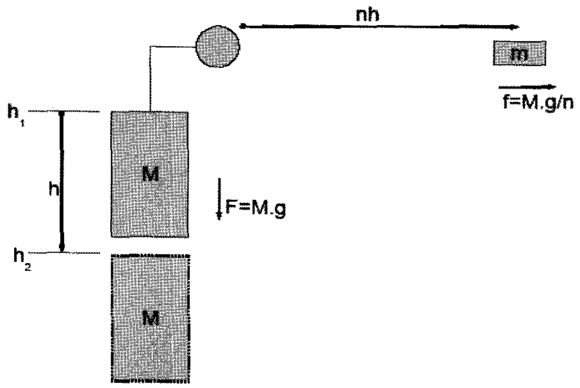

Fig. 1 Mathematical representation of basic principle.

$$M.g /n= m.a \quad (1)$$

$F/n=f$ where $F = M.g$ and $f = m.a$

where g is the acceleration due to gravity and a is the acceleration with which the mass m would move, at the time t1 if we allow the M to vertically move down.

Generally the value of "a" is only a fraction of g and let it be "k". By making "m" a fraction of M, say "p", we substitute in the equation (1), M.g/n=p.M.k.g or

$$n.p.k=1 \quad (2)$$

for ideal frictionless case.

2.1 Case of Moving a Mass from Rest

Now let us allow the M to move down to position h2, a distance of (h1-h2=h), under gravity, which will make the mass rolling to move a distance of n.h from its position of rest; in time "t" to reach a velocity of "v". Then we can write: t=v/a assuming the same uniform "a" is applied throughout.

$$M.gh=0.5\ mv^2 + 0.5\ M(v/n)^2 + Q \quad (3)$$

We may put dM.h=Q and increase M by dM, and the revised M if used, equation can be written neglecting the term Q. where Q is the energy lost in friction losses in gears rolling friction etc.

The gravity power driving the mass m at "v" is equal to m.a.v

At this stage the driving power is disengaged, assuming we have reached the desired speed v for the mass rolling; the kinetic energy of the M is now recovered into a flywheel storage unit, located in the tower, bringing the mass to a rest. The rolling unit has nothing to do with the flywheel storage.

2.2 Case of Maintaining the Cruising Speed of a Mass Rolling

As the rolling mass is moving at a speed v, to maintain the speed, it has to over come rolling resistance and resistance due to air and grade resistance, which occurs as an opposing force and if not overcome, causes a deceleration of Q/m, where fr is the resisting force. Further it is at speed v. So a power equal to m. (Q/m). v has to be provided.

$$F.(v/n) = m.\ (Q/m).\ v. \quad (4)$$

F being M.g where if M is kept constant, then we have to control n, the gear ratio, to satisfy this relationship. But we do need to note that the M has to be moving at v/n speed. But suppose the M was at rest, and needs to move at this speed, then we have to allow the M to move down under gravity, until it reaches this speed.

2.3 Case of Stopping a rolling Mass-recovery of Energy

The rolling mass required to stop will get engaged to the power-cable gear system to the mass M; due care taken to match relative speeds and assuring gradual imposition of deceleration through progressively adjusting the "n" value, which will cause the M to rise up converting the kinetic energy of the rolling mass as a potential energy gain to self, thus bringing the rolling mass to a halt. Obviously the M will not regain the original "h" value, but a little less, which represents the friction losses, hysteresis of the system. Let it be hr, that is the recovered height. So we can write

$$0.5\ m.v^2=Mg.hr \quad (5)$$

it is to be noted that had there been coasting without further input of power, the value of "v" in the equation (5) could be less accounting for the loss of momentum.

So the energy input required by an external source other than gravity, to bring back the M to its fully charged potential energy level, is Mg(h-hr). Generally the time over which this is required to be recovered is much more than the time that the M took to launch the mass m , and in a linearly oscillating system, the cycle time for the subsequent mass to be launched decides the time. That is the frequency of the service or the headway between two rolling masses will allow us to decide the power needed for the electrical motor to raise the mass back to position.

The losses can be estimated as:Rolling resistance is generally expressed as $Q=c+d.v+e.v^2$ where c,d and e are constants for the rolling mass, the value of constants determined through field experiments. Similarly for all the gear systems, and the high speed cable system supported on special rollers too will have a similar equation linked to the speed.

2.4 Effect of Grade and Curve

The grade resistance in one direction needs energy but in a double line, the same grade adds, so it is possible to balance the same. But curve resistance is lost and cannot be recovered.

In all the above relationships M may be taken as a set of masses of a number of Power mass modules grouped into a gravity Power Tower and the embedded intelligence coordinates the various activities based on inputs received from transducers located at appropriate locations providing information about speeds, distances and accelerations on a continuous basis of the rolling mass, the high speed traveling cable.

3. Gravity Power Tower

A typical Gravity Power Tower and components along with principle is summarized in the Fig. 2. The flywheel unit is not a primary driving unit. It is merely a flexibility to conserve any waste in usage of energy but has no primary role to play.

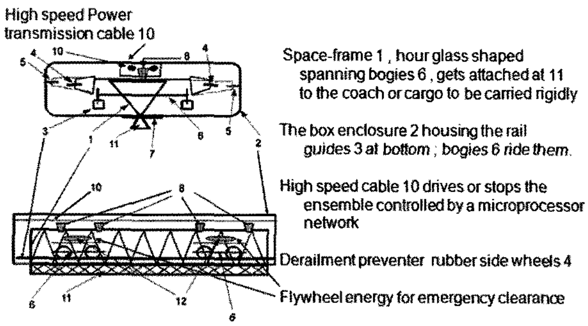

Fig. 2 Components of gravity power tower and principle

The Gravity Power Controller is set of networked microprocessors with built in intelligence and communication capability, with controllers on main gear system, the high speed power transmission cable and the rolling unit as well as with controllers of adjacent gravity power towers. The functioning is indicated in Fig. 3.

A set of inter-communicating microprocessors with distributed intelligence, form controllers of the main gear system in the Gravity Power Tower, the high speed power transmitting cable, the rolling unit and Power Mass modules. As shown in Fig. 3 these interact to balance the gear ratio to draw the correct motive force needed to drive or the resisting force needed to stop a rolling unit, as needed.

3.1 A Nomenclature for Classifying Gravity Power Towers

As described earlier a Gravity Power Tower will comprise of a number of Power Mass Modules, each with a driving mass, the size of the mass chosen based on requirements of the size of the mass on wheels to be driven. If we make a standard module of 500T, 250T and depending on the requirement of rolling mass we may choose a number of the modules of 500T or 250T modules, which facilitates standardization.

It is proposed that Power mass Module be named as P/M/h where P indicates Power mass module and M is the value of mass and h is the maximum vertical drop from the position of rest. So P/500/10 indicates that the driving mass is 500T and can travel 10 m which means it has 5000 KN as its potential energy.

A Gravity Power Tower will have a number of such modules as well as a gear-power transmission cable system. It is proposed to adopt Gr/aP/M/h where Gr qualifies the Grav-

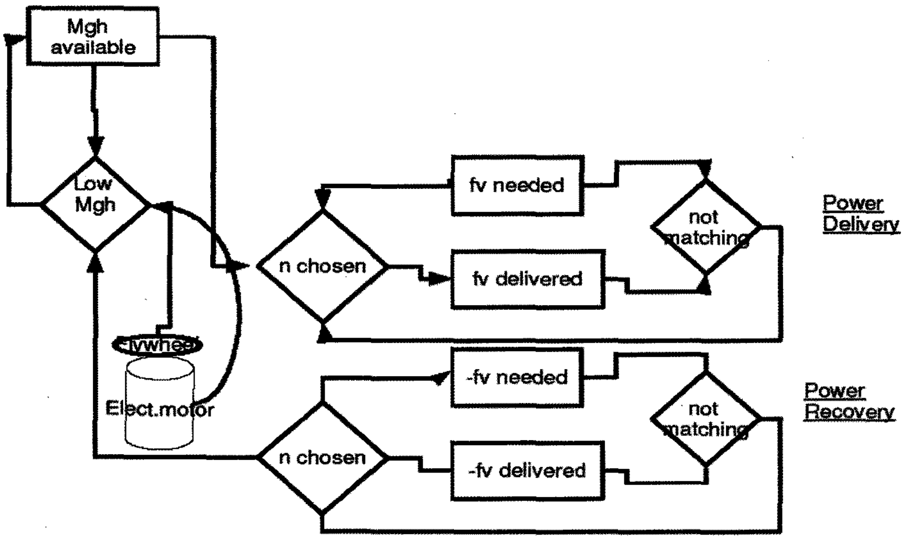

Fig. 3 An overview of knowledge based actions in gravity power tower

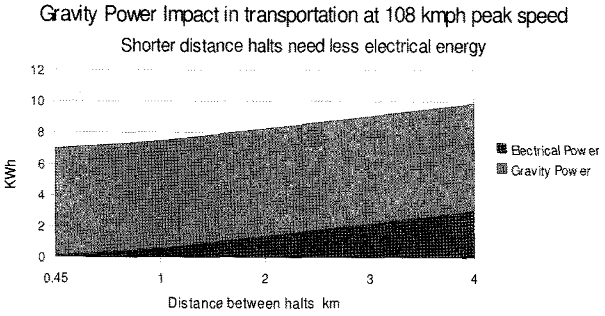

Fig. 4 Energy profile in gravity powered transportation.

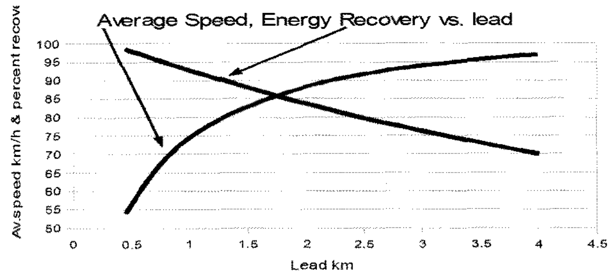

Fig. 5 Relationship of lead & energy recovery

ity Power Tower, a is the number of Power Mass Modules, followed by elements of the same. So Gr/6P/500/10 means it is a tower housing 6 nos of Power Mass modules each with 500 T mass and a10m range for vertical motion.

The length of the Power Transmission cables will be decided based on the rate of acceleration and the desired velocity for the rolling mass to be launched. But for the urban transportation since station to station distance is short, we can use station to station cable lengths, with the rolling unit continuously gripping the cable station to station.

It is important to note that the rolling mass unit in this system is simplified having no traction motors nor any other dynamically sensitive rotating masses, to cause complications for the dynamics of rail bogie. It is a simple case of a cable firmly holding at the pivot locations of the bogie and enforcing the sped profile, the wheel sets being free of any motor or powered gearing.

4. Practical Case of Short Haul Gravity Powered Rail Based Urban Transport

We cover here the method of evolving the design and operational parameters for a typical urban transportation case using the gravity power.

The mathematical results are first presented, showing also how the dynamic gear ratio changes with rolling friction.

The above calculations show we can use gravity power to move at average speed of 54 kmph a rolling unit of 50T, over 450 m on level, conserving 98.643% of energy-that is using Gravity power and recovering back the same. So we need to provide less than one and half percent of energy from external electrical source in the gravity tower to make up.

Figuratively, Fig. 6, for better appreciation the positions of driving mass and the rolling unit, the velocity vs time and energy vs distance, are indicated reflecting the above mathematical results.

The Fig. 4 shows how with lead the friction losses increase and though still energy from gravity constitutes 98% to 70%, we may need to supplement with electrical energy to restore the masses in the tower, to the extent of 2 to 70% depending on the lead we chose between halts in the city.

With lead average speed increases, the peak speed being 108 km in the city, from 54 to over 95 kmph, but energy recovery declines to a low of 70% (Fig. 5).

The dynamic gear ratio variation figure may be perused which indicates higher ratios for recovery because the rolling friction now assists deceleration, so decelerating force is lower than when we are driving the rolling unit (Fig. 6).

Attention is drawn to the fact that the driving mass M which is 1000T in this case will attain momentum by the time it completed accelerating the rolling unit, and when the mass is disconnected from the gear system, this energy needs to be directed to a fly wheel storage within the tower, or connected to another mass within the tower, to raise the same against gravity and lose thereby its kinetic energy.

4.1 A Case of 180 kmph Maximum Speed for Comparison

Referring to Table 1, we see that we can have average speed of 90 kmph, with stops at 1 km, and energy recovery of more than 95.5%.

4.2 Case of 360 kmph Gravity Powered Rail Transportation

From Table 2, we observe that rolling resistance values at higher speeds dominates, hence the recovery percentage drops. It is interesting to note that in Gravity Powered systems, we can continuously accelerate at 0.25 g, (g= acceleration due to gravity), which is not possible in case of electrically driven systems currently obtained. Hence comparatively the average speeds obtained even for short distance like 15 km, is very high.

Let us take a case where we accelerate at 0.31 g continuously to reach 360 kmph.

The average speed improves to 366 kmph, referring to Table 3, for lead of 33-34 km, as compared to 322 kmph, referring to Table 2 when 0.25 g was used for acceleration and deceleration.

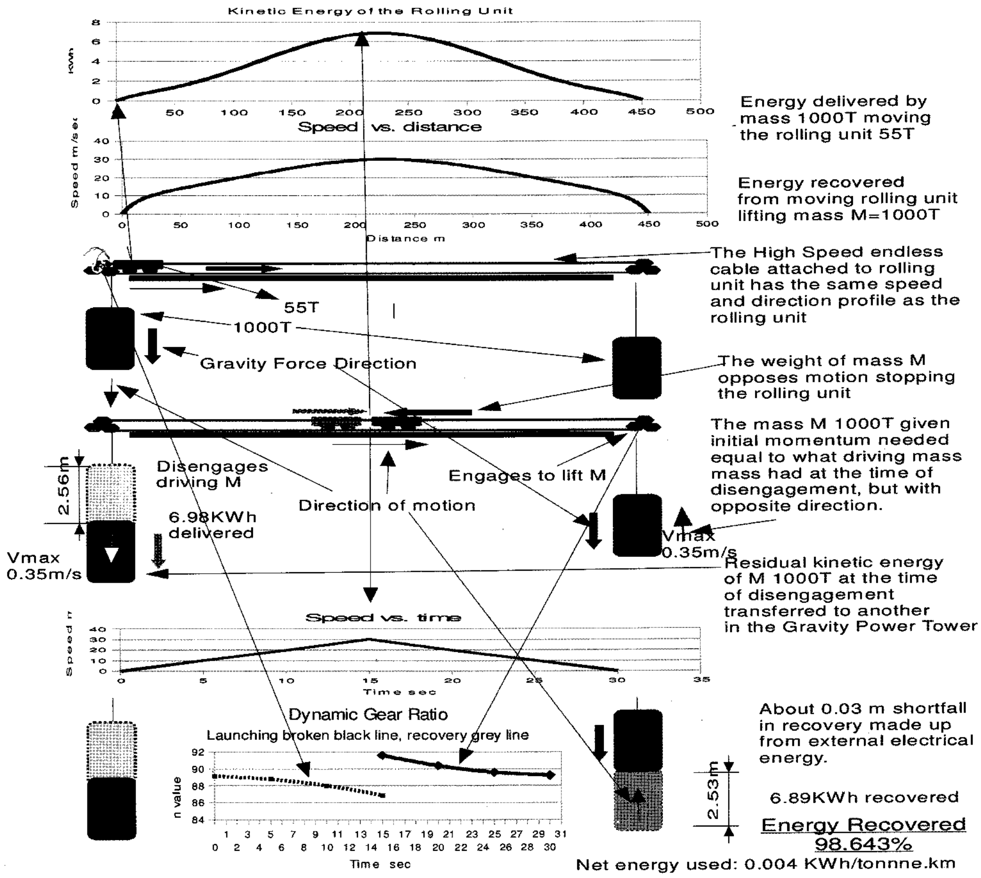

Fig. 6 Parametric summary of Gravity Powered transportation

Table 1. Gravity Powered 180 kmph transportation

Case of transportation at 180 kmph of 50T rolling unit.

Station to station distance km	1.00	6.00	11.00	16.00	21.00	26.00	31.00
Time sec	40	140	240	340	440	540	640
Av Spd kmph	90	154.29	165	169.41	171.82	173.33	174.38
Total Gravity Energy delivered	19.64	29.78	39.92	50.07	60.21	70.36	80.5
Net Kwh/1000 tonne.km	15.908	33.392	34.981	35.577	35.890	36.082	36.212
Average speed/peak spd.%	50	85.71	91.67	94.12	95.45	96.3	96.88

Table 2. Gravity Powered 360 kmph transportation

Case of transportation at 360 kmph of 50T rolling unit.

Station to station distance km	4.00	9.00	14.00	19.00	24.00	29.00	34.00
Time sec	80	130	180	230	280	330	380
Av Spd kmph	180	249.23	280	297.39	308.57	316.36	322.11
Total Gravity Energy delivered	84.18	121.75	159.33	196.9	234.48	272.05	309.63
Recovery of energy %	85.066	58.813	44.943	36.367	30.539	26.321	23.127
Net Kwh/1000 tonne.km	57.139	101.304	113.923	119.900	123.387	125.671	127.284
Average speed/peak spd.%	50	69.23	77.78	82.61	85.71	87.88	89.47

Table 3. Gravity Powered transportation accelerated at 0.31 g
*Case of t*ransportation at 361 kmph of 50T rolling unit.

Station to station distance km	3.35	8.35	13.35	18.35	23.35	28.35	33.35
Time sec	66.8	116.7	166.6	216.5	266.4	316.3	366.2
Av spd kmph	180.36	257.48	288.4	305.07	315.49	322.63	327.82
Total gravity energy delivered	83.24	120.96	158.67	196.39	234.11	271.83	309.55
Recovery of energy %	87.316	60.08	45.803	37.006	31.044	26.736	23.479
Nel Kwh/1000 tonne, km	57.355	105.163	117.150	122.604	125.722	127.740	129.153
Average speed/peak spd.%	50	71.38	79.95	84.57	87.46	89.44	90.88

The energy given during acceleration is what gets recovered back when decelerated. This practically remains constant, and the energy given for over coming the rolling friction to maintain the steady speed, is unrecoverable.

5. The Capacity and Throughput

The speed profile managed to allow the minimum distance between two moving rolling units adequate to stop under emergency braking condition of decelerating at 0.3 g for the relative speed between them. Additionally the length of one Power Transmission cable length is added because we depend on the cable to stop. So the minimum distance will be length of the power transmission cable. For an approaching rolling unit, the availability of berthing place decides the speed profile-either allowed to get in or brought close to the station, and slowed down to a halt just short of the station. So the headway can be improved providing for longer berthing line to accommodate one more rolling unit. So we can imagine launching a rolling unit ever time the preceding one clears the power transmission cable length ahead or Gravity Power Tower ahead. The time taken to recharge the Power Mass modules, is not factored in, because we use multiple number of them and so parallel activity occurs not affecting headway. So for a case of spacing between

Gravity Power Towers at 500 m, the time taken to cover the distance by the preceding rolling unit becomes the critical number deciding the headway. The time taken is dependent on the peak speed and the distance it takes to reach the peak speed. If this distance 'l' is less than the spacing of the Gravity Power Towers, then l=(0.5×v×v/a), and if l<500, the headway is sqrt (500×2/a). Otherwise the time is v/a+(500-l)/v.

Once the headway time is known we work out capacity per hour and per annum.

Therefore a Gravity Powered Rail can deliver 80 to 90 m passengers, or 80 to 90 m tonnes of cargo, or 4 m containers per year per direction.

6. Human Comfort

It is interesting to observe that with stops every one kilometer, taking only 40 seconds to cover, it may be acceptable for commuters in a city and such continuous acceleration, followed by deceleration, each being within permissible limits. So one can take advantage of energy recovery of 95.5%.

Table 4. Capacity of Gravity Powered Rail system

v m/sec	30	40	50	60	70	80	90	100
lm	152.91	271.83	424.74	611.62	832.48	1087.33	1376.15	1698.95
Headway	21.76	19.3	18.49	18.43	18.43	18.43	18.43	18.43
Add 5 sec for response time	26.76	24.3	23.49	23.43	23.43	23.43	23.43	23.43
Capacity								
Passengers/12 hr day at 150 per unit million	0.24	0.27	0.28	0.28	0.28	0.28	0.28	0.28
Annual 360 day year	87.16	96.02	99.29	99.55	99.55	99.55	99.55	99.55
Freight at 50T/unit, per 20 hr day, 360 day year m	48.42	53.34						
Containers 4 TEUs/unit m	3.87	4.27						

In case of long distance travel, say 100 or 200 km, if one experiences 100 to 200 times such dynamics, it is not considered acceptable. In such a case, even though we still have Gravity Power Towers located every one kilometer or even half a kilometer, stops could be limited. The energy conservation is improved by increasing stops, in gravity powered transportation, which is an interesting result.

7. The Gravity Powered Rail Module

The special construction features of the Gravity Power Rail Module are now described in a Fig. 7 below.

It is important is to note the substantially reduced unsprung mass on track. There are no electric motors and the the fly wheel energy storage is only a secondary element, for receiving energy from the moving rolling unit, drive a dynamo to provide emergency lighting or siren as needed.

The derailment preventer is a set of pair of solid rubber wheel sets mounted on extensible arms (4), which normally do not touch the sidewalls, but when either predefined acceleration limits (Bojji 1983, 1984) are reached or instruction received from the rolling unit controller, they get extended and butt against the sidewalls, to prevent derailment or escaping from the rail tracks, as well as built in disc brakes cause emergency braking, for which a compressed air cylinder provides the energy.

The Rail module's steel wheel set exactly the same as used in rail roads, rides over standard rail track, the track having a running opening in the middle to accommodate the downward extended space frame spanning the two bogies.

Effectively the Rail Module is rather simple, with no conventional traction motors or any traditional braking arrangements. The cargo container or the passenger coach is integrated with the Rail Module's space frame spanning the two bogies, as indicated in the Fig. 7. The system could be elevated or sub-way suspended coach type.

Themovement is totally controlled by the energy management and continuously positively held by the power cable and automated without any visible signals.

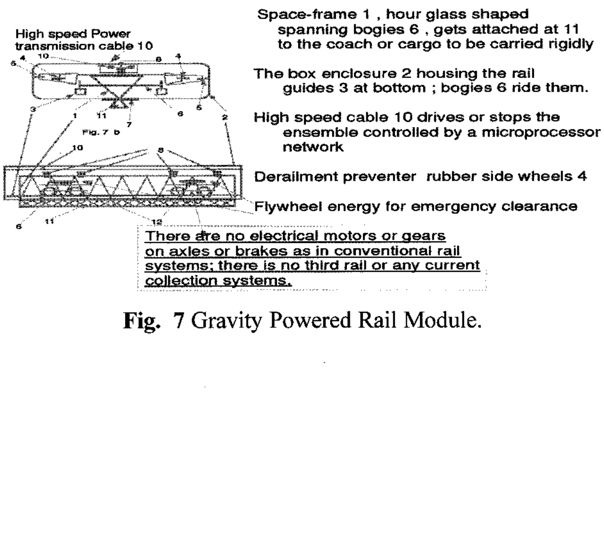

Fig. 7 Gravity Powered Rail Module.

Safety isenhanced as there is protection against derailment as well as capsizing of coaches, because the coaches cannot get separated from the tracks held inside the enclosure box, both for elevated and under ground options of gravity Powered Rail suspended systems.

Case of power supply failing and the train getting stranded in mid section away from station does not arise, because, unless adequate energy is available at the Gravity Power Tower to launch a suspended coach to reach the next station, the launching will not take place.

There are no emissions of fuel burning nor chances of electrical sparks or short circuits along the route of travel of the coaches, reducing vastly chances of fires and eliminating pollution too.

Theregular train signal control systems are eliminated in the Gravity Powered Rail system, as positive control by the launching and receiving

Power Transmission cables make sure of safety of the moving coaches and automatically controlled by the computerized control of the Gravity Power Control in coordination with the on board computer of the rolling mass

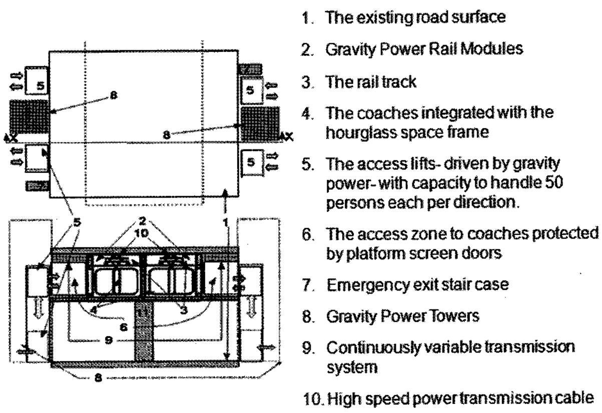

Fig. 8 Gravity Powered Elevated Rail transportation.

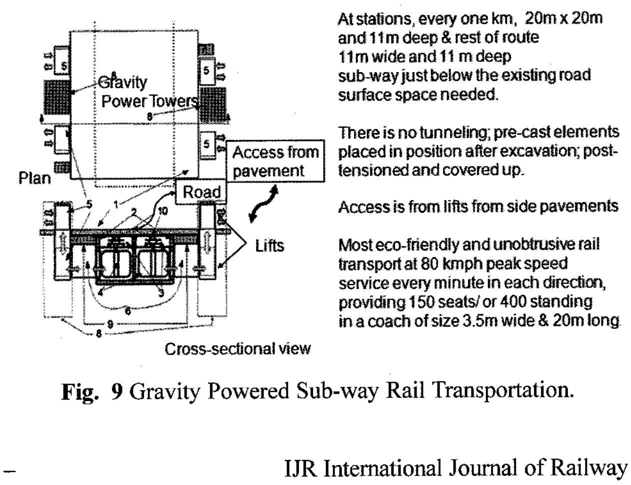

Fig. 9 Gravity Powered Sub-way Rail Transportation.

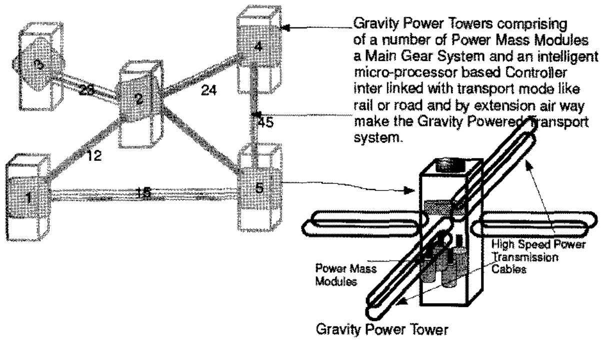

Fig. 10 A Gravity Tower network supplies energy.

Elevated Gravity Powered Rail [Bojji 1989, 2004 & Bondada et al. 2005]

Gravity Powered Sub-way Rail system

The lifts providing the access and the emergency exit steps may be noted and sufficient provisions for safe transit and disaster preventing and mitigating steps can be built in just as in case of existing metro systems.

The great advantage is the road grades can be followed as the rail based system is not dependent on the rail-wheel adhesion for tractive effort.

Sinceexisting right of way of roads is used, the system can be implemented without delays and it is environment friendly with no emissions and reliable as gravity.

So how does a city get a network of such gravity powered transportation is shown in the Fig. 10.

An over view of typical Specifications for constructing a Gravity Powered Urban Rail Transportation system is presented at Annexure A.

Nowfor costs and impact on energy scene of a nation. Take USA as example. For every Mwh of gravity power delivered by Gravity Power Tower, we need 10 to 30% as electrical energy to recoup. Depending on the source of electrical energy, this cost this will vary. The basic infrastructure cost to provide the gravity tower is really comparatively quite low. So the impact on a country's energy scene, taking the case of USA is shown in Fig. 11.

8. Summary

The new Gravity Power Towers, which comprise of Power Mass Modules with potential energy stored in vertically moving very heavy masses; a continuously variable gear & power transmission system to convert gravity power as motive power for rolling masses fraction of the size of the Power Mass Modules; to accelerate in horizontal direction at a fraction of acceleration due to gravity away from the Tower using High Speed Power Transmission cables; the said gravity tower recovering back the energy of the Power Mass Module raising the heavy masses back against gravity, from the kinetic energy of another approaching rolling mass through the High Speed power transmission cables, to the extent of 98 to 70% of the energy depending on the lead; the balance made up from external electrical source; a network of such Gravity Power Towers with High Speed Power Transmission cables linked with each other through rail/road or airways form the gravity power transport systems saving more than 70% of the energy used in transportation systems. Compared to electricity, gravity enjoys additional unique benefits of saving on generation and distribution costs. A case of 108 kmph peak speed urban transport with halts at 450 m is demonstrated to be almost completely powered by Gravity Power, needing less than 2% of electrical energy!

9. Conclusion

It is now possible to to put gravity to pro-actively power city urban transportation, inter-city high speed travel both for people and cargo, saving 98 to 70% of electrical energy and contributing to improving quality of human life at reducing costs, as well as global warming, because gravity is non-polluting and cannot be exhausted, further more, free of generation and distribution costs which makes it inflation proof. A policy initiative needs to be taken by the states to promote Gravity Powered transportation systems to progress towards energy independence.

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