High-speed Heavy Mass Energy Storage System with Multiple Identical Units

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***Abstract*— This paper presents a new heavy mass energy storage system which can more effectively lift up and lower down the containers with heavy masses at relatively low cost. It adopts an electric machine coupled with supportive rotary cylindrical wheel to have more coupling between driving machine and the belt used for lifting the containers with heavy masses. Such system can quickly lift up the containers with heavy masses in order to cope with intermittency of renewable generation. Although both double-sided and one-sided configurations work, the double-sided one can lift up and lower down the containers quicker.**

Keywords*— *Energy storage; heavy mass; vertical movement

I. Introduction

Nuclear fusion could be an ultimate high-tech solution to energy shortage but its commercialization is not foreseeable in the near future [1]. Moreover fossil fuel could be depleted within next 50 years [1]. Hence energy crisis is still a pressing issue faced by us. Grid-scale massive energy storage is currently in high expectations [2-4]. When striving for such massive energy storage solution, many limiting factors need be considered such as key materials availability. In the previous driving topology or configurations proposed by the author [5], a vast amount of permeable and stainless steels need be used. Although they are recyclable, massive or global-wide implementation may not be feasible. In another method in [4], the author proposed to use cost-effective method to lift up and lower down containers with heavy masses based on locomotives. Such system suffers from low efficiency. Given the fact that the materials such as iron ores etc on earth are limited, and they could be used up someday as well, designing a less-steel-use and relatively high efficient electric machine system is highly indispensable. This is the motivation of this paper.

The remaining contents of the paper are organized as follows: In Section II, the new topology of the machine system is described in detail; Section III concludes the paper.

II. DESCRIPTION OF THE SYSTEM

Fig.1a shows side view of such a heavy mass energy storage system, where there is one driving unit which contains one wheel driven by electric machine and another supportive rotary cylindrical wheel. Two wheels are mechanically coupled by steel belt with both protrusive stubs and punch holes. The punch holes are for coupling with stubs on the rotary wheels while the protrusive stubs are for coupling with the driving belts for lifting up and lowering down the containers sitting on container holders. Fig. 1b shows the top view of the system, where there are multiple identical units, each of which is installed with a combination of rotary cylindrical wheel and an electric machine, either being an induction machine, DC machine, synchronous machine or being reluctance machine etc.

More details of the machine system are shown in Fig. 2a, Fig. 2b, and Fig. 2c. Figure 2a is the top view of the driving machine with wheel and supportive rotary cylindrical wheel. The rotary cylindrical wheel is pivoted by grounded supports at its two sides as shown in Fig. 2c. Fig. 2b and 2d are the same as those in Fig. 1.

Fig.3 is the top view of the steel belt with punch holes for lifting containers sitting on the container holders. Punch holes are all the way along the belt between left-side and right-side container holders. The distance between two neighboring holes is nearly the same as that of two neighboring protrusive stubs on each wheel, including those distributed wheels at two-plus-two corners where driving belts linking containers holders turn. Fig. 4 shows the top view of the steel belt with both punch holes and protrusive stubs for coupling the wheel of the driving machine and supportive rotary cylindrical wheel. On the surface of wheels for both machine and cylindrical support are installed with protrusive stubs for coupling with the driving belt through punch holes. From Fig. 2c and Fig.4, one can see that there are two columns of punch holes and stubs. In practice, one column could work as well. There are also two columns of punch holes on the belt for lifting container holders and two columns of protrusive stubs on the machine-cylindrical wheel coupling belt.

In Fig. 1 and Fig. 2, there are two sets of lifting mechanism, one being formed by the left-side container holder 1A, outside vertical belt, left topside distributed corner support wheels, outside horizontal belt, right topside distributed corner support wheels, outside vertical belt, right-side container holder 1B and the other being formed by the left-side container holder 2A, left inside vertical belt, left inside distributed corner support wheels, inside horizontal belt, right inner side distributed corner support wheel, right inner side vertical belt, right-side container holder 2B. Instead of using both top and bottom sets, one set can be used.

The system is designed to work in both motoring and generating modes.

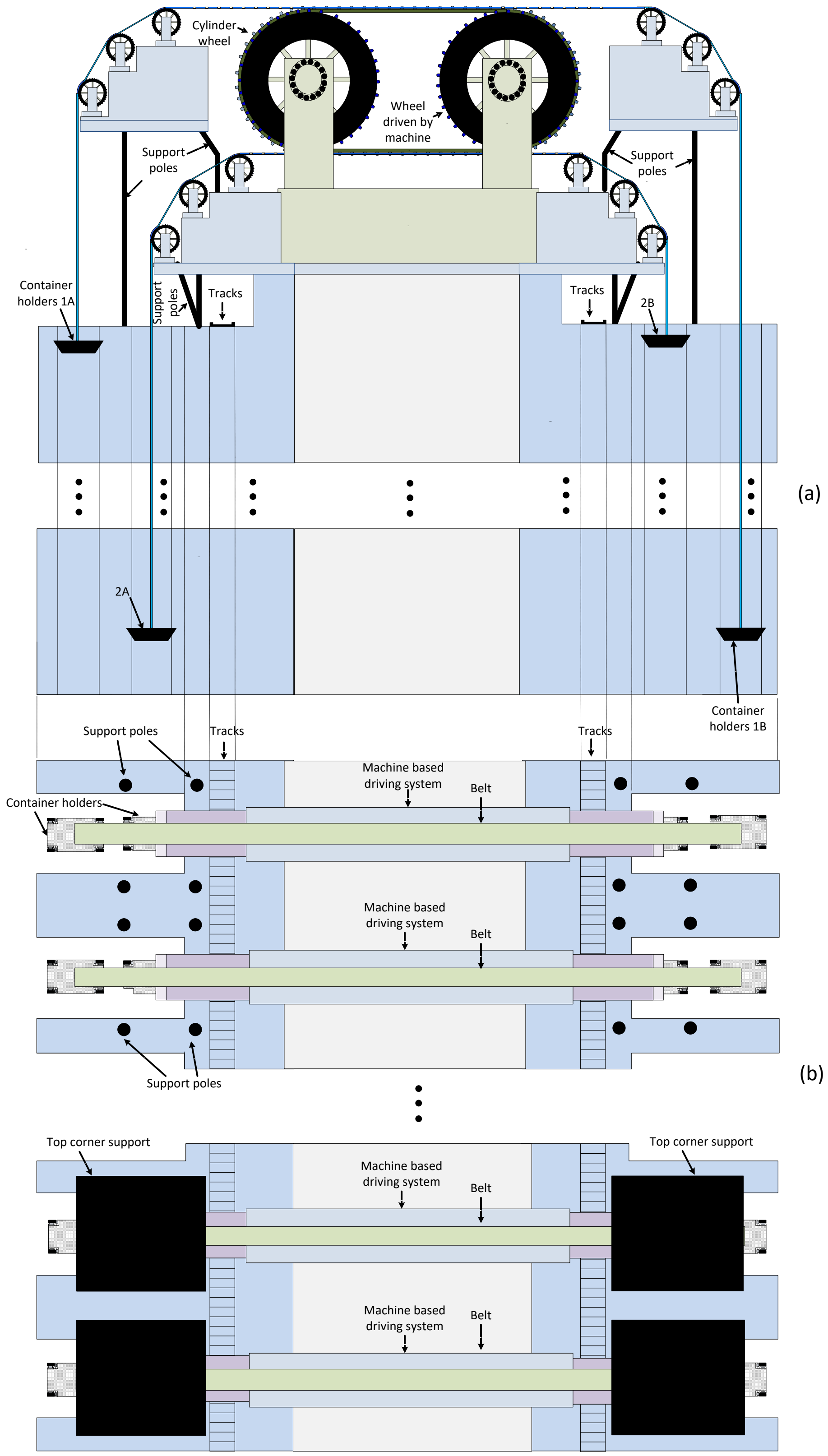

Fig. 1. Doubled-sided heavy mass energy storage system

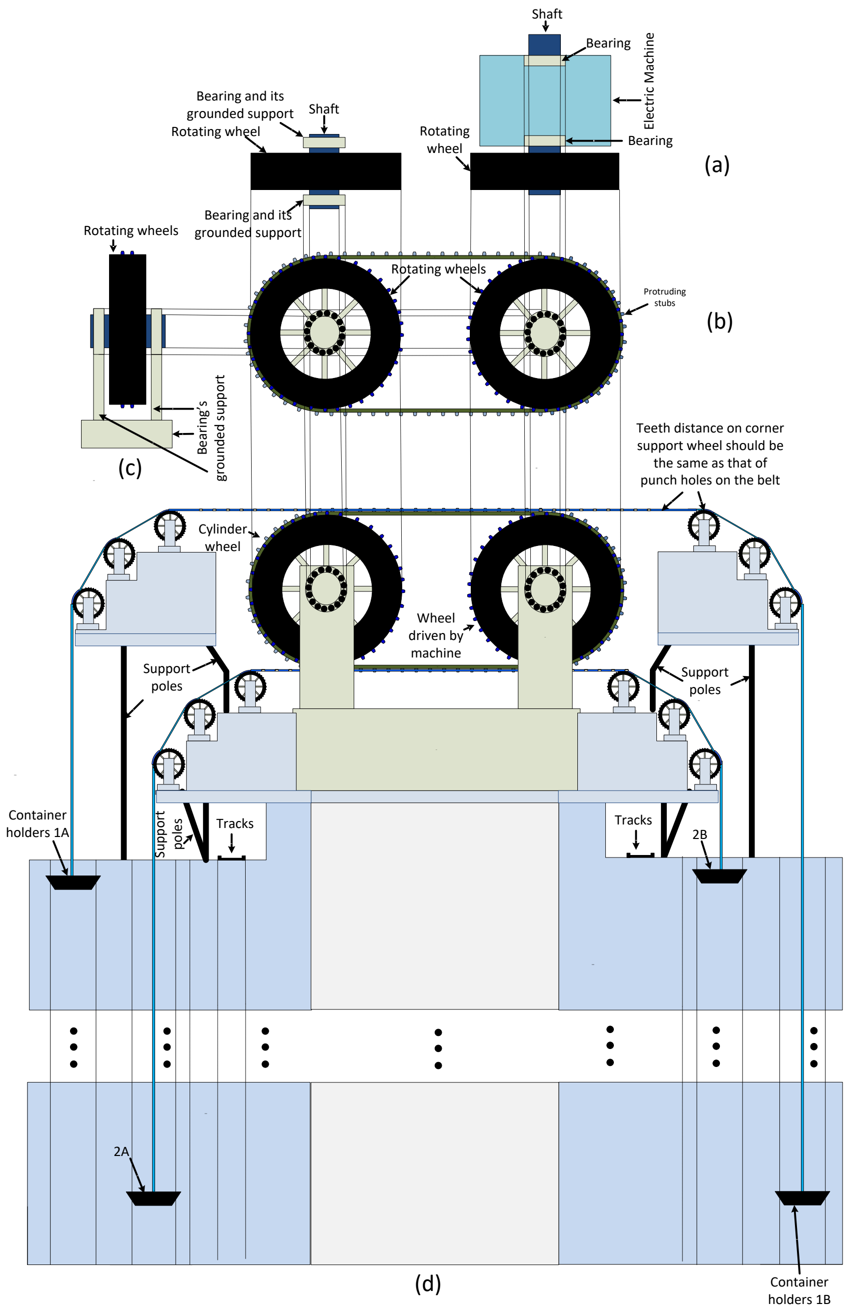

Fig. 2. More detailed electric machine system for lifting-up and lowering-down containers

When working in motoring mode, the following sequence is followed:

Step-1: Containers with heavy masses are placed onto the container holders 1B, and 2A in Fig. 1 at landing point of respective bottom parking lots. Then the electric machine rotates in the anti-clockwise direction. Both containers with heavy masses are lifted up through their vertical passages via supporting poles as shown in Fig. 1. In the meantime, empty container holders 1A and 2B are lowered down through vertical passages along their respective support poles.

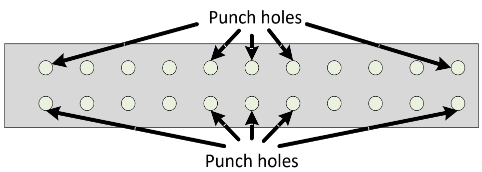

Fig. 3. Steel belt for lifting containers sitting on container holder

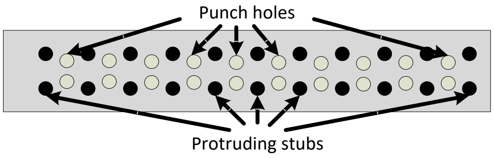

Fig. 4. Steel belt for electric machine coupled with support rotary cylindrical wheel

Step-2: When both container holders 2A and 1B with containers reach their respective tops of the vertical passages, electric machine stops. Robot arms move the containers with heavy masses from their holders and put them to the respective tracks. Then the containers are moved by mini-locomotives on each track to their final destination at high parking platforms. In the meantime the container holders 1A

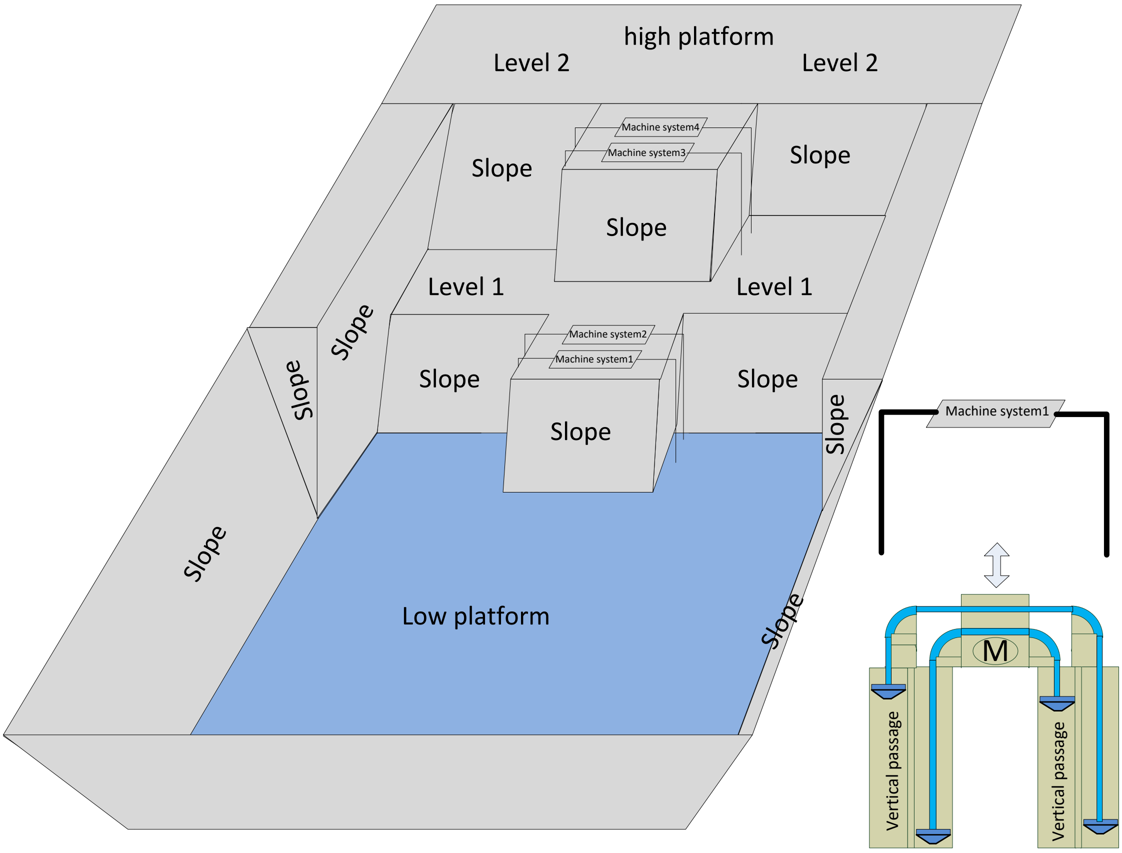

Fig. 5. Heavy mass energy storage with multiple levels

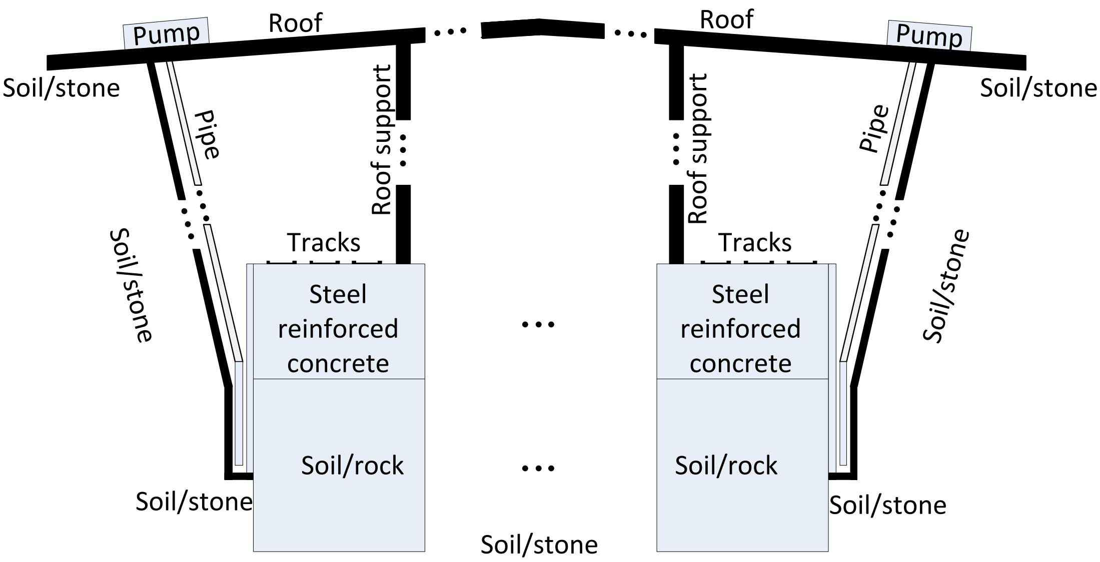

Fig. 6. Roof and drainage system for low parking platform

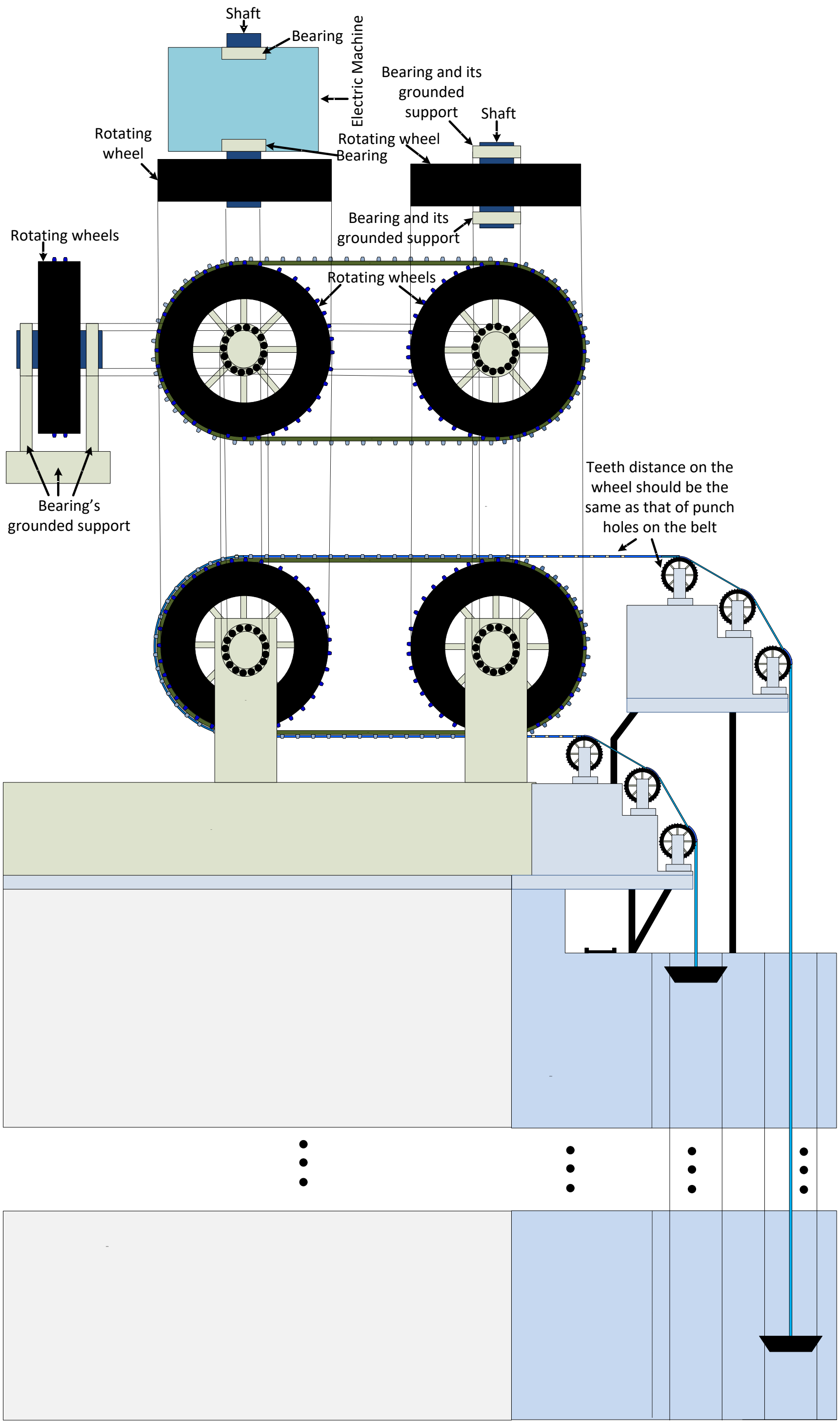

Fig. 7. One sided system

and 2B reaches bottoms of their respective passages and the containers with heavy masses are put onto them.

Step-3: Electric machine starts rotating in the clock-wise direction. The containers with heavy masses sitting on container holders 1A and 2B are lifted up along their respective vertical passages and container holders 1B and 2A without containers are lowered down through their respective vertical passages.

Step-4: When the container holders 1A and 2B with containers with heavy masses reach the tops of their respective passages, containers with heavy masses are moved by robot arms, then to tracks, then further moved to the final destination at the high parking platforms by mini-locomotives. In the meantime, containers with heavy masses are put onto the container holders 1B and 2A at their respective low parking platforms.

Then iteration repeats from step 1 to step 4.

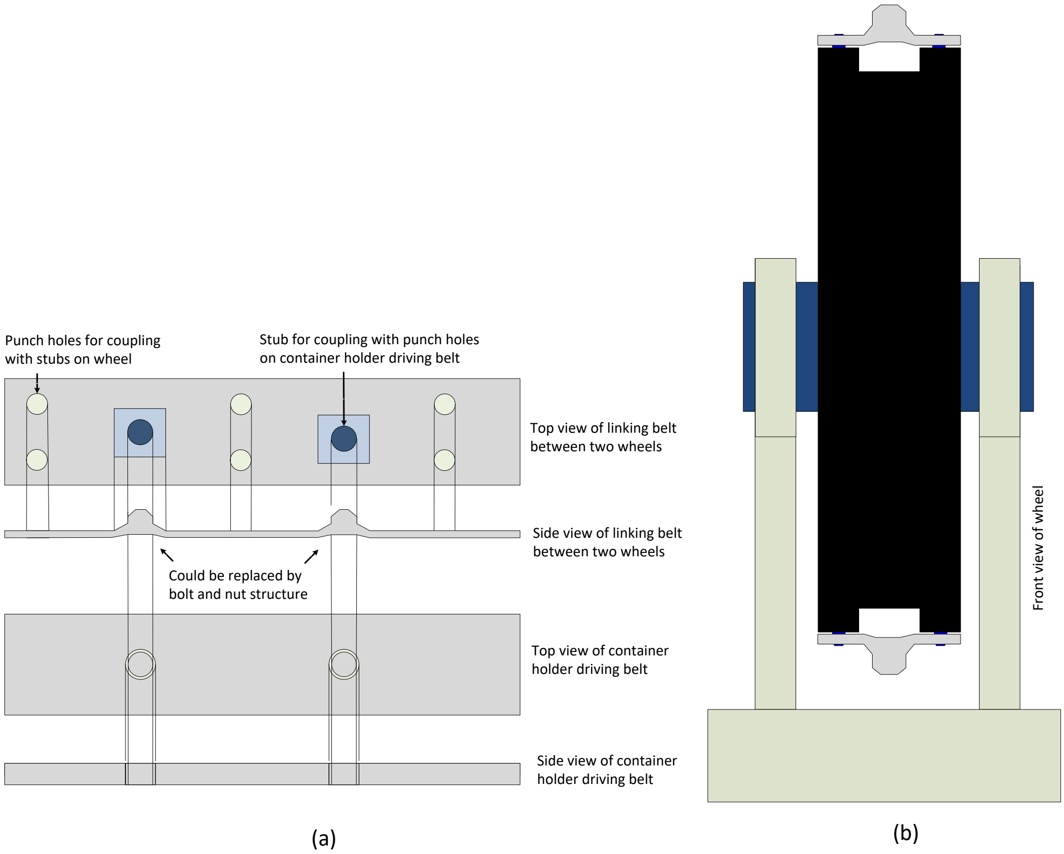

Fig. 8. A new coupling mechanism between belt and wheels

When working in generating mode, the following sequence is followed:

Step-1: Containers with heavy masses are put onto the container holders 1A and 2B. Then the electric machine rotates in anti-clockwise direction. The containers with heavy masses sitting on the container holders 1A and 2B are lowered down through their respective vertical passages while the container holders 2A and 1B without containers are lifted up through their respective vertical passages.

Step-2: When the container holders 1A and 2B with containers reach the bottom of their respective vertical passages, the electric machine stops, and the containers are moved by robot arms and put onto the tracks linked with low parking platforms. Then they are moved by separate mini-locomotives to their respective final destination at the low platforms. In the meantime, the containers with heavy masses are put onto the container holders 1B and 2A at the tops of their respective vertical passages linked with high platforms.

Step-3: The electric machine rotates in clock-wise direction. The containers with heavy masses sitting on the container holders 1B and 2A are lowered down through their respective vertical passages while the container holders 1A and 2B without containers are lifted up.

Step-4: When the container holders 1B and 2A with the containers with heavy masses reach the bottom of their respective passages, the electric machine stops. The containers with heavy masses are moved by robot arms and put onto tracks linked with low parking lots and further moved by separate mini-locomotives to their respective low parking lots. In the meantime, the containers with heavy masses are put onto the container holders 1A and 2B at the top of their respective vertical passage.

Then iteration repeats from step 1 to step 4.

When more energy needs be stored, a system with two levels as shown in Fig. 5 can be adopted. On each side, a slope is adopted to avoid accident. Only the two sides of those areas which accommodate machine systems are perpendicular. More levels can be used to store more energy. The vertical height of 50m to 80 meters for each level should be safe.

The proposed energy storage system should be used in dry land. By doing so, there is no danger of inundation of the low platform or parking lots. Nevertheless a roof-like structure and drainage system as shown in Fig. 6 is still indispensable to ward off water accumulation due to rain, snow etc.

Instead of using double sided system as shown in Fig. 1 and Fig. 2, one sided system could be also used as shown in Fig. 7, where there is still a combination of one driving electric machine and one supportive rotary cylindrical wheel for each of multiple identical units.

Furthermore to increase the overall lifting weight of the container by the driving machine system, a new belt and protrusive stubs are designed and shown in Fig. 8. The top two figures in Fig. 8a show the top and side views of the belt for coupling two wheels, and the bottom two figures show top and side views of the belts linking two container holders on either side. Fig. 8b is the front view of one of two identical wheels for the driving machine and supportive cylinder as shown in Figs. 1 and 2. Design of the protrusive stubs on the surface of the belt coupling two wheels in the machine driving system is a challenge. Fig. 8 shows one possible structure which has upward bent for easiness turning on the surface of the wheels.

Each of the three distributed support wheels at each of two-plus-two corners as shown in Fig. 1 and Fig. 2 can be the same or as large as that in Fig. 8b or the wheel of electric machine or cylindrical support wheel.

To have higher efficiency, it is necessary to use less amount of mass weight in each container, as little as several hundred kilograms to several tons. By doing so, friction losses in each driving unit are kept low. To achieve the same level of energy storage, multiple identical units need be installed at each of multiple levels as shown in Fig. 5.

Instead of using robot arms to mount and dismount containers from the container holders, another more efficient method could be as used, which is described below.

A common container support during movement is formed by four-wheeled base, container stainless steel shell with pivotal protrusion to be coupled with the four-wheeled base as described in [4]. The container holder needs to have four short and shallow grooves to position the four-wheeled base.

For the upward movement, when the container holders with containers sitting on the four-wheeled bases reach the top of passages, bridging steel plates are released to bridge neighboring container holders and steel rods are placed to join the hooks on two sides of each container shell. Then robots or mini-locomotives are to pull then push the lined containers sitting on each four-wheeled base to either new container bases for next level movement or to final destination.

For the downward movement, when the container holders with containers sitting on the four-wheeled bases reach the bottom of passages, steel rods are placed to join the hooks on two sides of each container shell. Then robots or mini-locomotives can pull then push the lined and joined containers sitting on each four-wheeled base to either new container bases for next level movement or to final destination.

In the same way, when the containers are prepared for movement from low to high platform, lined containers at the low platform are pushed to the lined container holders sitting at the bottoms of each vertical passage for multiple identical units.

When the containers are prepared for movement from high to low platform, lined containers at the high platform are pushed to the lined container holders sitting at each of the multiple identical units. Each time steel rods are used to join the shells covering the containers sitting on each four-wheeled base for movement. Once the containers reach respective container holders, rods are removed.

As the container could be quite thin and tall, other supportive mechanism needs be used to position the containers during movement along the vertical passages.

As described in [4], multiple four-wheeled base, container shells, steel rods are built to increase efficiency of moving containers.

III. CONCLUSION

This paper proposes a cost-effective heavy mass energy storage system which can more quickly lift up containers with heavy masses in order to cope with intermittency of renewable generation. Such system uses less steel compared with other proposed methods. Furthermore multiple identical units are used and each one handles less heavy masses. Therefore the system could work with relatively high efficiency at low cost.

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