# Research on Energy Saving through Potential Energy Recovery System (PERS) of an Electric Forklift

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Abstract: This research looked on the energy saving on electric powered forklifting machine. In as much as there is better energy saving and less environment emissions in electric systems, it was noted that there was a lot of energy losses and leakages during the lifting process. The research checked and simulated using Simulink models the possible Potential Energy recovery during lifting and lowering. Potential Energy Recovery System (PERS), made it possible to realize energy regeneration which is then saved in batteries and supercapacitors. The combinations of electric motor (PMSM), Supercapacitors and batteries complimented one another on to achieve a considerable energy saving of above 70% from possible losses. The simulation results are a testimony of possible savings and pointing to an area worth investing in real life engineering systems. Further research in this area is promising further energy saving not only in forklifts but in all automotive industrial equipment. The savings maybe realized by electronically synchronization of actuators, energy storage systems and mechanical lifting mechanism with real-time feedback and correction mechanisms.

Keywords: Forklifting machine, PERS, Regeneration, Supercapacitors and Simulink model

#### 1. Introduction

Energy efficiency is becoming a major research area in all fields of engineering and the technologies related to these engineering fields are of utter most importance. Currently, the dominant forklift trucks are LPG/petrol powered forklift, diesel powered forklift and electric powered forklift (1). Concerning energy saving in Electric Drive lifting system of Forklifts (EDLSF), it is known that a small energy saving on one device would mean a large energy saving, this is so because there are large numbers of forklifts used in the world of industry and commerce. Although use of EDLSF does save a lot of energy as compared to convention systems which include hydraulic and electro-hydraulic, further researches have indicated further energy savings (2).

Minav at el, 2012, explained that, not only lifting and lowering of goods waste a great deal of energy, but also speeding up and braking are typical running characteristics of forklift which consumes energy (1, 3, 4). When energy consumption is reduced by improving the energy efficiency of a machine, harmful emissions will also be reduced somewhere in the energy chain. It is against this background that ways to improve the energy efficiency are now studied widely owing to tightening emissions standards set to limit the global warming (5). According to Minav at el, (2012), the two main recoverable forms of energy in working machines are the kinetic and potential energy. In this research, the researcher is going to look on energy saving technologies on EDLSF through a thorough review of existing systems, investigations and analysis using Matlab simulation.

## 2. Related Literature Review EDLSF

This chapter covers literature review on general working principle of an electric drive system of a forklifting, characteristic of forklift truck's working flow and Potential Energy Recovery System (PERS). The reviewed literature will give the basis and necessary aiding information for this research paper.

#### 2.1 General Working Principle of an Electric Fork Lift

In an electric forklift, the electric motor drives the gearing system whereas the other engine powers the hydraulic pump which, similarly as in gasoline, drives trucks equipped with hydrostatic transmission(6-8). Then the motor drives the pump which then powers the hydrostatic and other mechanisms. Through the analogy to other vehicles, in particular rail vehicles, drive units of fork lift trucks permit the recovery of energy while braking(9, 10). The characteristic feature of any truck's work is the continuous accelerating and braking(11). During breaking the energy is dispersed into the environment as heat. In working drive units which are mainly the lifting and lowering system one may consider the recovery of potential energy of forks lowered by gravitation. Practically, during the braking process the same amount of energy could be recovered as is consumed during acceleration and load lifting(12-14). While lifting loads, energy equivalent to the lowering energy could be recovered. In comparison, the energy consumption on drive at a steady speed is less compared to the energy consumed to accelerate the truck. It is worth estimating the values of energy fluctuations and considering the opportunities to recover energy lost while slowing down the truck and lowering load.

#### 2.2 Characteristics of Forklift Truck's Work

For the researcher to know where to tap in and serve energy, the route characteristic of a forklift truck's work needs to be considered and analyzed. Taking an example in the warehouse setup, let us assume that a forklift truck handles the loading of vehicles with palletized load transported from a rack. The truck transports the pallets from the middle of the warehouse to vehicles waiting at the ramp. This process

Volume 9 Issue 11, November 2020 <u>www.ijsr.net</u> Licensed Under Creative Commons Attribution CC BY is shown in Figure.1, numbers in bold designate the typical position in truck's work. The description of the working cycle is presented in Table 1.



Figure 2: Forklift truck working cycle while loading a vehicle

#### **Table 1:** The description of the working cycle

No.	Operation Number	Name of Operation	
1	1-2	Withdrawing an empty forklift truck from inside the vehicle	
2	2-3	Travelling to the rack to pick the pallet	
3	3-4	Raising the fork to the middle level of the rack	
4	4-5	Inserting the forks under the pallet and moving the truck ahead	
5	5-6	Raising the pallet up by 2 cm.	
6	6-7	Taking the pallet out of the rack	
7	7-8	Lowering the pallet.	
8	8-9	Reversing the truck in the aisle.	
9	9-10	Travelling ahead with the pallet	
10	10-11	Lowering the pallet onto the vehicle floor	

The results of energy saving will be more visible if there are more stages of unsteady travel than those at steady speed. The question may be answered by a minimum time analysis of the truck along the set route. The travel is described in Figure 2.



Figure 2: Model minimum time travel

In summary, a typical work cycle of a forklift mainly includes the following: five parts: running from the initial position to the cargo position, lifting forks with cargo, moving and transporting, stacking the cargo and unloading. Fromthese working cycles, there are eight main working conditions, including walking, steering, lifting without a load, lowering without a load, up-tilting of forks, downtilting of forks, lifting with a load and lowering load. Amongst them, there is more recoverable potential energy in the lowering load condition. This is the main point of the PERS of a forklift and the research thrust will be on this.

#### 2.3 Review on Potential Energy Recovery System (PERS)

Due to low noise, zero emission, pollution-free characteristics, pure electric drive construction machinery becomes a new development direction of construction machinery (2, 15)(14). Electrification of the forklift is developed early and is relatively mature in the field of construction machinery. However, currently, the pure electric forklift on the market uses the low voltage system basically and the rated load is under 5-ton, which are called

small type forklifts. There is a lot of gravitational potential energy that can be recovered for all the forklifts. Their lifting system frequently reciprocates up and down and converts the potential energy into heat energy, causing high temperature of the hydraulic system and the short life of hydraulic components (3, 8, 16, 17) In view of the above, Minav et al did a lot of researches on the PERS for the electric forklift. In the year 2014, the feasibility of load potential energy regenerated was predicted, and the influence of different loads and different descending velocity on potential energy regeneration was analyzed (1, 18). Also, the efficiency of the electric motor (EM), hydraulic pump and valves were analyzed (3). The energy saving efficiency of the system was measured, and the advantages of the electric pump drive system were verified (2). On another research, the PERS of the electric forklift with a lithium battery was built, and the regeneration efficiency of the system at a different velocity was analyzed (19)(20) Li et al. proposed a forklift with the power system of a battery-EM-hydraulic pumpanalyzed (21). The test results showed that the energy regeneration efficiency could be up to 40%(22)(23) The efficiency of PERS was increased

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by 18% in the low speed mode and 30% in the high speed mode(24). In a similar research, Jiang et al. controlled the valve group to drive the hydraulic motor to make EM generate electric energy when the boom is descending, and stored the recovered energy into the battery of the forklift. The regeneration efficiency was up to 20% (25). These researches verified that the potential energy could be regenerated and the regeneration efficiency was high.

## 3. Simulation and Results Analysis

This chapter covers results from MATLAB Simulink model of the electric lifting systems on energy saving simulation. Graphs from Simulink plots are included in this chapter and results shown from the plots highlighted and explained. Also measured values from actual related set up are considered for comparison purpose to substantiate the simulation results. Discussion of the results is also covered in this chapter.

#### 3.1 Results, Analysis and Verification of the MATLAB

Simulink model on Figure 3 illustrates the dynamic simulation results: speed, torque, pressure and position of forks for a payload of 920 kg with an internal gear pump and 4.5kW PMSM. The speed and the torque have some ripple in this operation, and a better controller or a smoother speed reference should be used.



**Figure 3:** Simulated speed, torque, pressure and position for lifting a payload of 0 kg



Figure 4: Measured speed, torque, pressure and position for lifting a payload of 920 kg

Figure 4 illustrates the measurement results: speed, torque, pressure and position of the forks for a payload of 920 kg with an internal gear pump and 4.5 kW PMSM. The speed in Figure 3 follows the motor ramp measured from the test setup. Figure 4shows pressure and torque increase similarly at the beginning to overcome friction, after which they remain constant, and decrease slightly when the speed is reduced. The Position plot shown in Figure 3 demonstrates how the fork moves from its initial zero position to the maximum fork height. When comparing Figures 3 and 4, it can be concluded that the dynamic simulation gives results that are comparable with the measurement results. Table 2illustrates empirical and simulation data for the combination with the internal gear pump and the 4.5kW PMSM. It can be seen that the results from the simulation match the experimental results to an acceptable degree.

 Table 2: Results of Energy and energy efficiencies for lifting for payload 920 kg and speed

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Values	Measurements	Simulation
Height of movement (m)	1.7	1.67
Potential energy, (J)	50 800	51 000
Hydraulic energy, (J)	53 800	53 700
Energy from the shaft to hydraulic	68 900	67 800
mechanical conversion (J)		
Motor energy (J)	80 300	79 400
Efficiency of the hydraulic part (%)	94.5	95
Electric motor efficiency (%)	85.8	85.4
Efficiency from the shaft to	73.8	75.2
hydraulic-mechanic conversation		
(%)		
Hydraulic pump efficiency (%)	78.1	80.9
Total lifting efficiency (%)	63.3	64.2

#### 4. Discussion

The presented work is a system engineering model of an electric drive forklift with potential energy recovery systems. The behavior of electric lifting system components of the forklift system was simulated in Matlab Simulink. Presented

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model considers the different responses of the parts in the system. The model created is a system engineering model giving acceptable results. However, it does not include all the possible details for example. about the fluid flow behavior and is limited by the accuracy of the model. Also notable is that, the electric machine model has been created based on the machine parameters that do not fully and accurately describe the machine behavior allowing some mistakes in the efficiency. Because of the mentioned shortfalls, further research of all the models to make them more accurate is worth future work. Hereafter, the model was verified by measurements, and energy efficiency studies of the system were carried out. The verification of model by measurements shows that the energy and efficiencies can be estimated fairly accurately for an electric forklift.

From the research, it was discovered that frequent up and down operations of its lifting system constantly convert potential energy into heat energy. To capture theenergy loss, the paper proposes a potential energy recovery system of electric forklift truck driven by asynchronous generator, battery and Proportional Integral (PI). Experimental results show that recovered potential energy increases up to 3 886.82 J for a maximum increase of 920kg in load at the speed of 1200 r/min under the control mode, meaning potential energy recovery efficiency up to 79.29%

#### 5. Conclusion

In this section, a sum up of the findings as the researcher navigated through the research objectives. The researcher looked back on the background and research questions to discuss if the main purposes of the research has been fulfilled, and what other general conclusions that can be drawn from this research.

The energy storage systems which are batteries and supercapacitors all showed some short falls for example, supercapacitors can store less energy as compared to batteries but on the other hand, supercapacitors have fast energy charging and discharge. The research resolve use of both as they complement one another on enhancing energy saving, efficiency on power supply and storage

The electric motor (PMSM) during the forklift lowering travel, is driven to the reverse direction thereby giving the energy regeneration through the regeneration systems. The simulation results realized about 79 % energy saving from PERS. So, in summary, the research was success and the findings are of engineering value in the field of energy. Nevertheless, the research was not exhaustive and further research can realize better setup and savings as the research was limited on system simulation and analysis, which does have shortfalls on the actual physical system.

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