



Analysis And Applications of Solar and Flywheel Energy Storage System in Indian Railway

KEYWORDS

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ABSTRACT The application of unique world leading high-speed flywheel energy storage & Solar Energy Storage to real-time power management and voltage support for the traction industry.

Awareness for the need of sustainable and ecofriendly mobility has been increasing and various innovations are taking place in this regard. A study was carried out to assess the feasibility of installing solar photovoltaic (PV) modules atop train coaches. Feasibility of supplementing diesel generator sets with power from solar PV modules installed on coach rooftops has been reported in this communication.

It is now the most advanced commercially available Flywheel energy storage system. Its unique features, zero maintenance, 20 year life and high cyclic capability make it ideally suited to applications in rail power supplies.

The flywheel & solar system can resolve many of the problems encountered in traction supplies due to the 'peaky' nature of the loads caused by trains accelerating and braking. In addition, the flywheel & solar system can provide energy savings by improving the system's

receptivity to energy from trains with regenerative braking.

Comparison Of Technologies:

Parfomak claims that energy storage technology has great potential to improve electric power grids; in order to allow expansion in renewable electricity generation, and provide an alternative to crude oil based fuels in the transportation sector. (Parfomak, 2012) Electrical energy storage devices essentially convert electrical energy into other forms of energy, chemical energy, which can be stored and used when required. The option of the ESS for an application is dependent on its power, energy ratings, response time, weight, volume, and operating temperature. Table 1.1, shows the details of different types of energy storage systems.

	BATTERY (LiFePO4)	SUPERCAPACITOR	FLYWHEEL
Energy density (Wh/kg)	90-120	1-4	40-60 metal 140-350 composite
Cycle life	500-1500 (3000)*	1000000	5000000
Self discharge	lower than 10% (3%)* per month	50% of initial voltage per month	2-5% per minute
Operating Temperature	-30°C +60°C	-40°C to +65°C	-40°C to +150°C
Safety	Good	Good	Better
Toxicity	High	Less	Less

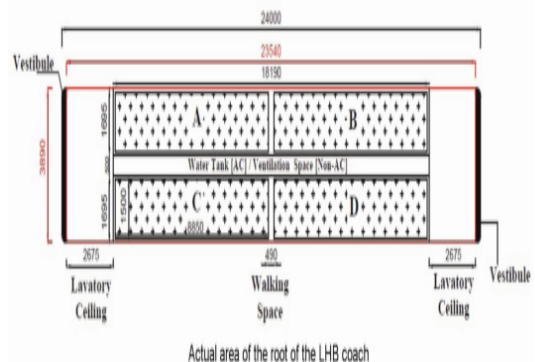
SOLAR ENERGY STORAGE SYSTEM FOR INDIAN RAILWAY:

A sustainable and ecofriendly mobility is indeed for innovations. To assess the feasibility of installing solar photovoltaic (PV) modules atop train coaches, a study was carried out. Linke Hofmann Busch (LHB) coaches do not have self-generating systems, thus making power cars are used to supply the required power for lighting loads. In this communication, Feasibility of supplementing diesel generator sets with power from solar PV modules installed on coach rooftops has been discussed.

Conservation of fuel is not only important, there is also benefit of a reduction in CO₂ emissions. Area available on coach rooftops is more than sufficient to generate the required power, during sunlight hours, for the electrical loads of a non-A/C coach even during winter. We had taken standard roof as the reference. Diesel price is taken as Rs 66/litre, there will be annual savings of Rs 5,900,000 corresponding to 90,800 litres diesel per rake per year by implementing this system. The installation cost of solar modules would be recovered within 2-3 years. This system would also give amount to an annual reduction of 239 tonnes of CO₂ emissions.

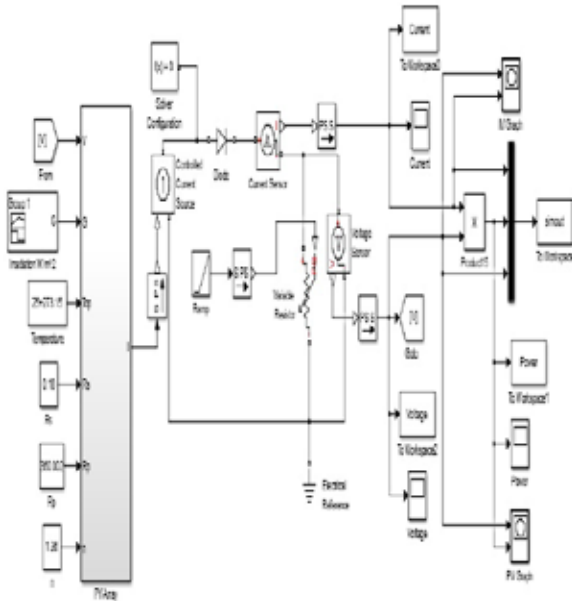
Rooftops Area Of LHB Coach :

To mount solar PV modules on the rooftops, it is vital to consider the dimensions of the coach. The entire area of roof surface cannot be used for installing solar PV modules; there have to be clearances that allow personnel to access the top easily for various purposes and associated auxiliary equipment on the rooftop. This would mean that the actual area that is available for fixing solar PV modules is much less than the total surface area of the roof. For the convenience of calculation, the entire area on the roof of a coach shall be divided into four equal parts separated by walkways, as shown in Figure 2.



Connected electrical load in the AC coaches	26 kW
Connected electrical load in the non-AC coaches	4.6 kW
Connected electrical load in the pantry car	10 kW
Net electrical load in the rake	212.14 kW
Net lighting load in the rake (considering 19 coaches, including pantry car)	90 kW*

Power Consumption of Electrical Loads in LHB Coach: Mathematical and simulink modelling of PV array:



RESULT OF MODELLED PV PANEL

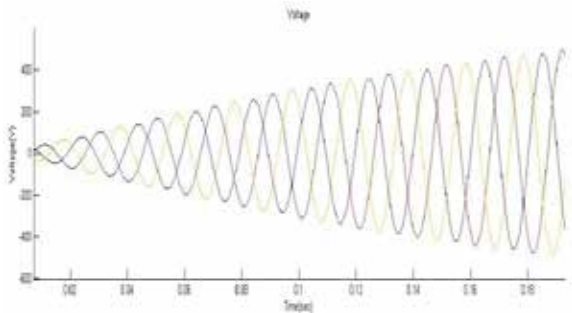


Fig. output of an inverter

Flywheel energy storage system for Indian railway:

The use of flywheel to store energy is not a new technology. Basic flywheels such as stone wheels were used to craft pottery thousands years ago. The stone wheel smoothens the pulsed power from the foot and enabled a smooth rotation of the pottery turntable. Under the industrial revolution the use of the flywheel increased significantly when the steam engine was introduced. During this period technological development of flywheels started. The first milestone was when Dr. A Stodola showed that certain shapes yield uniform stress distribution for isotropic materials. The next milestone in flywheel development took place during 1970's when applications for backup-power and electric vehicles were proposed. During this period flywheels made of composite material was proposed and built. The devel-

opment continued during the 1980's when magnetic bearings were introduced. Recent developments in materials, magnetic bearings, microcomputers and power electronics have made it possible to consider flywheels as competitive option for electric energy storage.

The energy scenario in the world is calling for efforts towards more efficient use of electrical energy as well as improved quality of its delivery. Due to limited budgets, the alternative is having different levels of supply quality. This issue involves the usage of equipments applying the concept of energy storage devices like batteries or flywheels. The demand for these equipments is increasing and thus their usage is increasing more and more. The type of energy storage system that is most widely researched and used especially in the last period is the Flywheel Energy Storage System (FESS) & Solar Energy Storage System(SESS). Due to the advancements in machines and power electronics, the flywheel is becoming more popular. Many feasible projects employing the FESS have been implemented all over the world.

System Description:

The basic circuit consists of an energy storage system, power electronic interface and a series transformer as shown in Fig. The energy storage system in this case is a flywheel coupled to an induction machine. The induction machine is used for energy conversion. The power electronic interface consists of two voltage sourced converters connected through a common DC link. One voltage source converter interfaces with the energy conversion and storage system and the other with the shipboard power system. The flywheel energy storage system has three modes of operation:

- Charge mode
- Stand-by mode
- Discharge mode

During charge mode, the VSC interfacing the shipboard power system runs as a rectifier and the other as an inverter, with the transferred energy accelerating the flywheel to its rated speed. In this mode, energy is stored in the flywheel in the form of kinetic energy. The energy flow is from shipboard power system to flywheel with induction machine as energy converter.

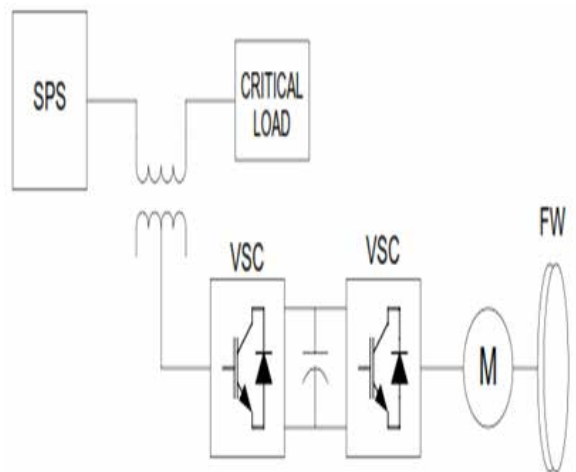


Fig. Basic circuit of flywheel energy storage system

SIMULINK MODEL OF FLYWHEEL SYSTEM:

We have modeled and simulated our system using SIMULINK which includes power electronics models and con-

trol and logical signals. Modeling with MATLAB is possible but the control and logic blocks and signals are hard to implement.

Modeling and simulation was done for a 3-phase system power supply. Thus the inverter/rectifier bridge is modeled as a 3-phase inverter. However, implementation of the system is done as single phase.

We have simulated one model in the project but working for both charging & Discharging Mode. All the components in the two models are the same except for the controller of the inverter.

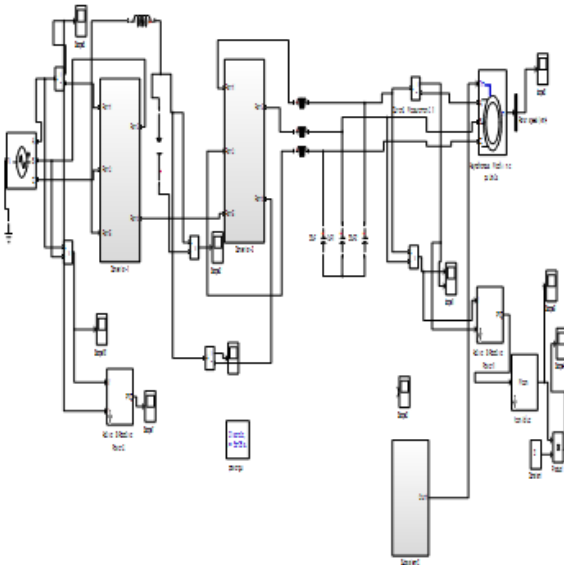
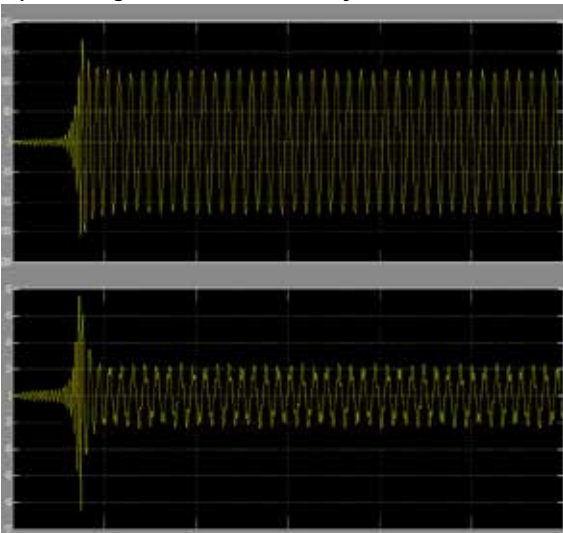


Fig. Simulink Model of flywheel energy storage System

Input Voltage & current to The flywheel Machine:



Future Work:

FESS can be implemented for several usages in the future. The power electronics parts, i.e. the inverter and the boost converter, with their controls, can be the back bone of other energy storage systems such as batteries or super capacitors since such energy storage devices use the process of bi-directional power flow. They could also be used with different renewable energy sources producing DC voltages such as a wind farm with rectified output, a solar array, or a photovoltaic array.

As for future work in power electronics, a 3-phase inverter could be implemented to supply 3-phase loads or to be synchronized with the grid.

Concerning the machine, high speed and high power machines are preferable for such systems (FESS) so that they can supply power to a larger load for a longer period of time. Such machines are not available at AUB and they could be part of a future research. The improvement in the electric machine is the important for any advancement in the system. The rotational speed of the machine affects mostly the stored kinetic energy in the flywheel and thus the time the FESS can supply the load.

Conclusion:

In this project, we have discussed the Solar & flywheel energy storage system (SESS&FESS). The system basically includes a two way energy flow scheme so that energy is injected into the flywheel in the form of kinetic energy, and drawn from the machine driving the flywheel in the form of electric energy. After showing the block diagram for our system and providing some general system description, we have presented alternatives for all the components that are needed to build the SESS&FESS. Advantages and disadvantages of these alternatives have been discussed, and then the components required were chosen depending on their availability, performance, cost and reliability.

Then we modeled our design using SIMULINK, and simulated it in order to verify the results. We have modeled our Solar & flywheel as a capacitor and added a resistor in parallel to model the voltage drop in the generator DC voltage. The obtained results were very close to the anticipated ones, and our design model is thus verified.

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