International Journal of Innovative Technology and Exploring Engineering (IJITEE)
ISSN: 2278-3075 (Online), Volume-9 Issue-5, March 2020

Rooftop Solar and Wind Power Based Hybrid Energy Storage System for AC Railway Traction

Nilam Jadhav, Shashikant Bakre, Ashpana Shiralkar, Sanjay Bangale, Nilambari Devarkar

Abstract— The conventional AC/DC Railway Traction Systems are undergoing number of improvements. Thanks to modern technologies such as Renewable Energy Systems (RES), Energy Storage Systems (ESS) and Hybrid Energy Storage Systems (HESS). At present the traction transformers cater electric supply to traction motors and auxiliary loads which may not be adequate enough to meet demands. Furthermore in the event of failure of traction supply, the alternative source of supply is required. This papers suggests a noval method of feeding auxiliary loads through the integration of RES and ESS. Solar and Wind power are vital renewable energy sources. The pros and cons of proposed method are also discussed in this paper.

Keywords- Hybrid Energy Storage System (HESS), Supercapacitors, Battery Energy Storage System (BESS), Solar PV, Wind Generator

I. INTRODUCTION

The traction is the process that involves movement of vehicle such as train [1]. The traction systems are categorised as electric and non-electric. The conventional electric AC Traction system mainly comprises of Traction Transformer, Centenary, Traction bus, Pantograph, Distribution Transformer and three phase AC Induction Motors and Gear Mechanism as shown in fig.1. Although DC traction systems are also available, now-a-days the AC systems are preferentially used. The supply received from EHV line (e.g. 132 kV bus) is stepped down to a traction voltage of 25 kV using Traction Power Transformer.The 50 MVA, 132/25 kV transformer is used in electric traction system. It is carried away by the 25 kV bus and centenary to Overhead Equipment's (OHE) of locomotive or Wagon. Electric supply to railway locomotives is fed usually through 25 kV bus.

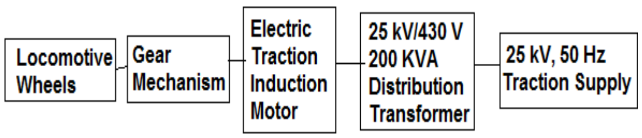

Fig. 1 Conventional AC Railway Traction System

Revised Manuscript Received on March 30, 2020.
* Correspondence Author
Ms. Nilam Ganpat Jadhav, Lecturer, Government Polytechnic Awasari College, Pune, India.
Dr. Shashikant Madhukar Bakre, Professor, Department of Electrical Engineering, AISSMS Institute of Information Technology College, Pune, Maharashtra, India.
Mrs. Ashpana Shiralkar, Head, Department of Electrical Engineering, AISSMS's Institute of Information Technology, College, Pune, Maharashtra, India.
Ms. Nilambari V Devarkar, Lecturer, Government Polytechnic, Awasari College, Pune, India.
Dr. S. V. Bhangale, H.O.D, Department of Electrical, Government polytecnic awasari khurd, India.

The 25 kV supply is then fed to the distribution transformer where it is stepped down to 430 V supply. The output of distribution transformer is then given to the three phase induction motor. The Induction Motor converts electrical input to mechanical rotations. Gear System which is used in the wheels of the train are rotated.

II. PROPOSED METHOD

Two constraints are associated with the conventional system. First, the traction transformers catering supply to traction motors and auxiliary loads may not be adequate enough to meet demands. Second, in the event of failure of traction supply, the alternative source of supply is required. Research is going on all over the world to run trains independently on Renewable Energy Sources (RES) [2]. For instance, Nagpur Metro is developing electric train fuelled on RES in Maharashtra, India. However, this paper suggests to retain traction supply for motors and use RES-HESS combination to meet auxiliary loads such as lighting, air conditioners, fans, auxiliary control circuit of traction motors and fire monitoring [3][4]. The detailed elaboration is furnished hereunder.

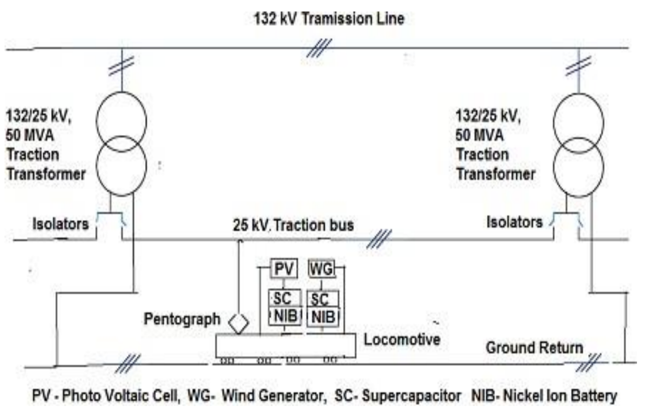

Fig. 2 Schematic Concept diagram of Traction Supply and HESS

A. Rooftop Renewable Energy Sources

It is proposed to install Solar PV system and Wind Generator at the top of train roof. The blades of wind generator rotate and generate electricity during the movement of train. When the train is not moving the wind generation would not be there. Under this situation, the auxiliary supply would be catered by an alternative source i.e. PV or HESS. Adequate clearance should be maintained between these two sources. As shown in fig.2, these two sources are connected independently to the selection scheme of auxiliary load. Depending on selection criteria, the supply is catered to the load.

B. Hybrid Energy Storage Systems (HESS)

If renewable energy is not available, the Energy Storage Systems (ESS) are provided as an alternate source of supply. It is quite evident that if one source of RES caters supply to the auxiliary load, the other source if available would be unutilized. For instance, if solar and wind source are available, one would be selected to cater supply and the other would be standstill. The energy from the other unutilised source can be stored in Hybrid Energy Storage System (HESS) as discussed below.

C. Lithium ion battery

The energy can be stored in battery preferably Lithium Ion battery. However, the Lead Acid Battery could also be used. Lithium Ion battery is preferred because of the following significant features.

- Lithium Ion batteries can be deep cycled.
- The constant voltage for about 80% of discharge curve is maintained by Lithium ion battery cell.
- Thus it delivers full power down to 80% compared to 50% given by the lead acid battery.
- Thus it provides more storage capacity.
- There is a very low amount of self-discharge to the extent that the batteries can hold charge upto 10 years. The charge-discharge efficiency is around 100%.
- The cycle life is around 1000 to 3000 deep cycles.
- It has a high energy density.

D. Supercapacitors

Supercapacitors are provided adjacent to the battery forming Hybrid Energy Storage System (HESS) as shown in fig 3. Generally, Supercapacitors are used to supplement batteries. However they can also be used as a main power source.

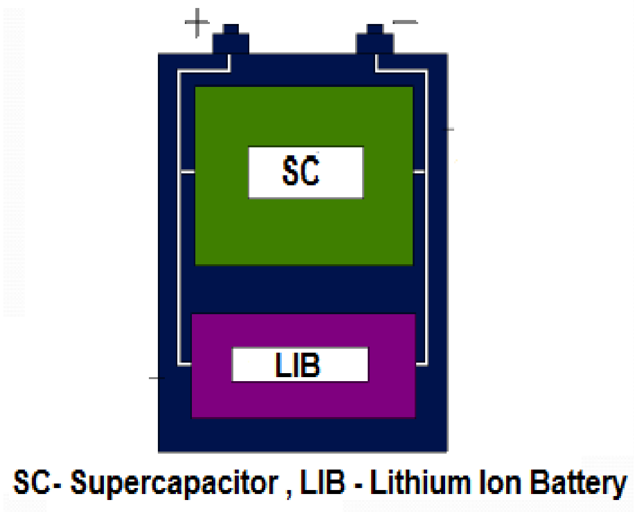

Fig.3 SC-LIB based HESS Supercapacitors offer significant features as given below.

- High power high energy source.
- Fast charge-discharge i.e. quick response.
- High energy efficiency of about 95% to 98%. The efficiency of lead acid battery is around 60% to 80%.
- Long life of about 15 to 20 years.

The comparison between Supercapacitor (also called Ultra capacitor) and normal battery is shown in Table 1.

Table 1 – Comparison between Ultra capacitor and battery.

ITEM	Ultra capacitor	Battery
Charging Time	1-30 sec.	1 – 5 Hours
Discharge Time	0-30 sec.	0.3 – 3 Hours
Energy Density (Wh/Kg)	5 to 15	20 to 150
Power Density (W/kg)	2000 to 10,000	20 to 150
Charge/Discharge Efficiency	95 - 98 %	60 - 80 %
Recycle Life	500,000 to 1,000,000	500- 1000
Temperature range	-50 to +70 °C	-10 to + 40 °C

The working of battery and super capacitor is complementary. When the battery is discharged the Supercapacitors charges it and at the same time, caters the load. Similarly, when Supercapacitor is discharged, the battery charges it Show fig 3. HESS are efficient, lightweight, pollution free and cheaper storage systems[5].

E. Source Selection Circuit

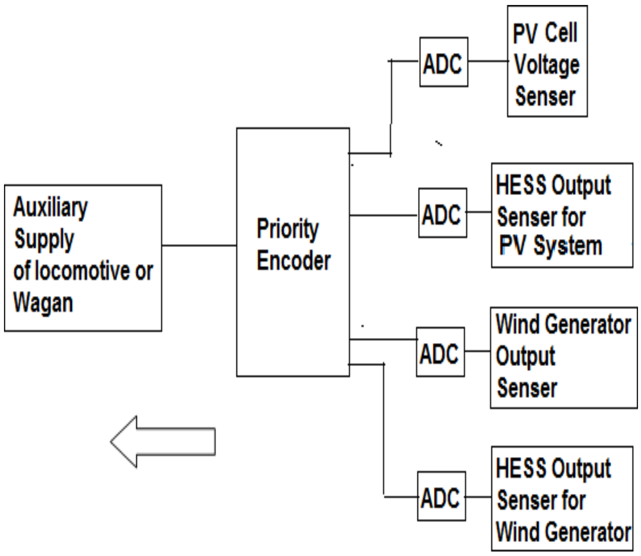

Fig. 4 Selection scheme for Auxiliary Supply

The four sources of auxiliary supply are there, namely PV Cell Voltage Senser, Wind Generator Output Senser, HESS Output Senser for PV and Wind Generator. The output of these sensers is Analog. Using Analog to Digital Converter, these Analog outputs so obtained are converted to digital form [3]. It is required to select the respective source as per availability. For instance during daytime solar power is available whereas during movement of train, wind power is available. The flow chart shown in fig. 5 gives the logic for source selection can prepare logic as per requirement.

International Journal of Innovative Technology and Exploring Engineering (IJITEE)
ISSN: 2278-3075 (Online), Volume-9 Issue-5, March 2020

III. METHODOLOGY

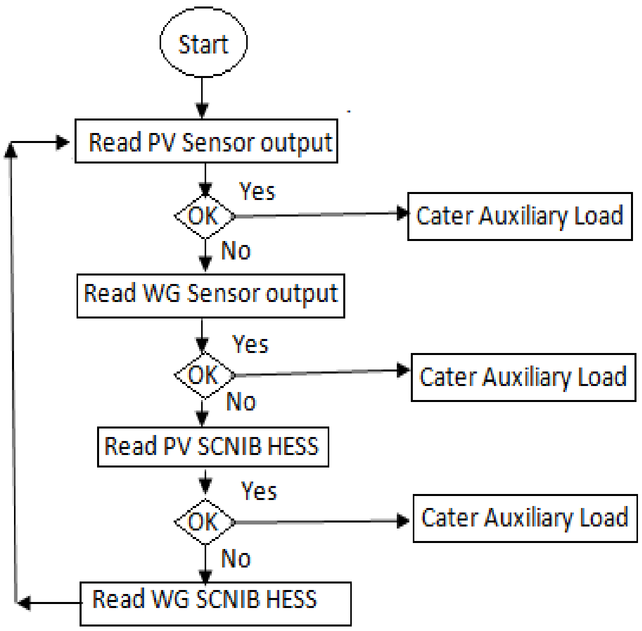

Fig. 5 Flow Chart for source selection

The source code is prepared as illustrated in flow chart and embedded in the chip called priority encoder. The output of priority encoder enables the selected source of supply.

In a nutshell, the overall working is summarized as follows.

1. Traction transformers feed supply to traction motors. The auxiliary load is catered by the proposed method in a following manner.
2. Rooftop solar PV system is mounted on top of the locomotive [5].
3. Rooftop wind generator is mounted on top of the locomotive.
4. SC-LIB based HESS is provided to PV system.
5. SC-LIB based HESS is provided to the wind generator.
6. The source selection scheme is developed and connected to the auxiliary load [6,7].

IV. DESIGN OF HYBRID TRAIN

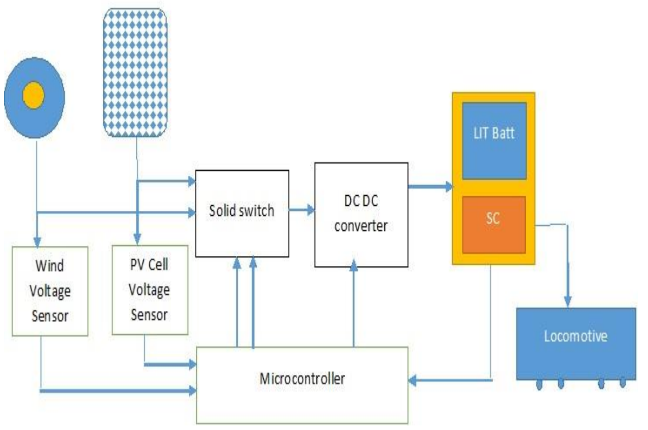

Fig.6 Design Of Hybrid Train

The working of battery and super capacitor is complementary. When the battery is discharged the Supercapacitors charges it and at the same time, caters the load. Similarly, when Supercapacitor is discharged, the battery charges it.

This work implements a smart boost converter to enable an electric traction to be powered by a solar, battery/super capacitor hybrid combination. A DC motor was retrofitted onto a normal geared motor powered by a lithium ion battery pack. A super capacitor module was connected in parallel to the battery pack via a custom made microcontroller-based boost converter which arbitrates power between the battery and super capacitor. The control algorithm for the boost converter was developed using a practical approach by using various sensor inputs (battery/supercapacitor current and voltage, motor speed) and comparing the robustness of control scheme.

Solid switch is used to select the healthy available power by sensing input voltage with the help of sensors this output is applied to DC dc converter for charging the battery as well. But in battery system a supercapaictor is connected in parallel with the battery operates in hybrid. i.e. in hilly areas requires a extra power for motor this may result battery deep discharge result my life of battery. So such condition a SC handled this power at that condition and SC charges in regenerative mode. The overall action done by a algorithm in microcontroller system.

V. BOOST CONVERTER OPERATION

There is yet another way of thinking about the operation of a boost converter.

The energy stored in an inductor is given by:

$$\frac{1}{2} \times L \times I^2$$

Where L is the inductance of the coil and I is the maximum peak current.

So some store energy in the inductor from the input and transfer that same energy to the output though at a higher voltage (power is conserved, obviously). This happens many thousands of times a second (depending on the oscillator frequency) and so the energy adds up in every cycle so you get a nice measurable and useful energy output, for example 10 Joules every second, i.e. 10 watts.

As the equation, the energy stored in the inductor is proportional to the inductance and also to the square of the peak current.

To increase output power our first thoughts might be to increase the size of the inductor. Of course, this will help, but not as much as we think! If we make the inductance larger, the maximum peak current that can be achieved in a given time decreases, or the time taken to reach that current increases (the basic equation $V/L = dI/dt$), so the overall output energy does not increase by a significant amount! However, since energy is proportional to the square of the maximum current, increasing the current will lead to a larger increase in output energy. So that choosing the inductor is a fine balance between inductance and peak current.With this knowledge can being to understand the formal method of designing a boost converter.

VI. PROS AND CONS

The benefits and limitations of the proposed method are discussed below.

Pros

1) Reliability.
The implementation of the proposed method makes auxiliary supply more reliable as number of alternate sources are available.
2) Economy
Despite adding number of sources these is no significant rise In capital cost of the system. The return on investment is also achievable in shorter time.
3) Simplicity
The proposed method is simple and easy to implement. The maintenance is also easy and cost effective. The trouble shooting is also easy.
4) Adoptability
The components required to build the system are easily available and adoptable.
5) Sustained development
The proposed system is totally pollution free and environmental friendly.

Cons

1) EMI issues

The 25 kV line may cause Electromagnetic Interference with adjacent solar and wind generator distribution lines. The mutual inductance may be formed between the lines which may result in inductive interference. The research is required to be conducted in dealing this problem. The feasibility of conventional method of transposition need to be studied.
The other important factor is a safety of human beings doing maintenance and troubleshooting works. They would have to work in induction zone of 25 kV distribution line. Proper safety measures would be required to be adopted as per IE Rules,1956 [8].

2) PQ issues

Number of components in the proposed method is nonlinear which are the sources of high order harmonics. Harmonic distortion takes place when electricity is controlled by electronics. The effects and mitigation of harmonic under this situation should be studied [5,6].

VII. SIMULATION & RESULT ANALYSIS

In this project the proteus simulation can be used. First the program should be burned into Arduino controller. Input voltage may vary to any value but with the help of PMW TL494 duty cycle of this adjusted through arduino Uno.the wind can generate voltage upto 4-9v. In this ardunio controller shows three voltages on display 1. Generated voltage 2. Battery voltage 3. Mains voltage designing a prototype model for traction system where we can use this dc-dc boost converter to charge the battery. In this project boost converter is used to step up voltage & stable voltage. In japan due to natural disaster train stop at one point to avoid such kiosk japan implement the battery energy storage system. Here trying to implement prototype model of train so we need battery storage system in which energy can be stored and use this energy in any natural disaster condition. We need 12 V battery, to charge this dc-dc boost converter is used which charge the battery up to 14.4V to maintain the output voltage constant we use PMW TL494 with ardunio controller. Fig 7 show constant voltage waveform of boost converter. When wind is not available then battery & supercapacitor can be used to constant running of train.By controlling duty cycle output voltage of boost converter maintain constant for any change in input voltage. Here ardunio controller play key role. This controller shows three voltages: Generated voltage, Battery voltage and Mains voltage. Normally battery of railways charged through 25KV catenary overhead supply. Rectifier house is near to each station. Regenerative energy generated from braking action is normally fed back to OHE, here we can used wind & solar to provide energy for train when solar & wind is not available then battery & supercapacitor can used to provide energy to train when battery is discharge supercapacitor is charge it & when supercapacitor is discharge battery will charge it[10,11]

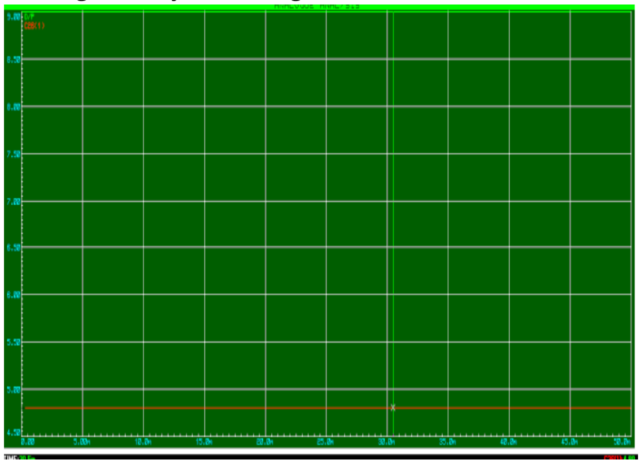

Fig.7 boost converter constant waveform

VIII. CONCLUSION

This paper suggests a noval method of feeding electric supply to the auxiliary loads of railway traction system through the integration of RES and HESS technologies. Solar PV and Wind power generators are suggested for roof top installation. The wind energy is generated during the movement of train and fed to cater auxiliary loads. The unutilized energy can be stored in HESS formed from the combination of Supercapacitors and Lithium Ion battery. The pros and cons of proposed method are also discussed in this paper. When the battery is discharged the Supercapacitors charges it and at the same time, caters the load. Similarly, when Supercapacitor is discharged, the battery charges it. The benefits of the proposed system are reliability, economy, simplicity and adoptability. The limitations of the proposed system are EMI and PQ related issues, which require detailed research and development.

Retrieval Number: D1560029420/2020©BEIESP
DOI: 10.35940/ijitee.D1560.039520
Journal Website: www.ijitee.org

Published By:
Blue Eyes Intelligence Engineering
& Sciences Publication

REFERENCES

1. James Larminie, John Lowry, Electrical Vehicle Technology Explained, Wiley Publishing.
2. S.S. Thipse, Alternative Fuels – Concepts, Technology and Developments, Jaico Books.
3. A.J. Bouwens, Digital Instrumentation, Tata McGraw Hill edition.
4. Electrical Transmission and Distribution Reference Book, Westinghouse Publishing, USA.
5. Dr. S.M. Bakre, Smart Grid, Nirali Publications, Pune, India
6. Dr. S.M. Bakre, Dr. Priya Gokhale, Electric Smart Grid in Easy Steps, Amazon Publishing, USA.
7. Sunil Mishra, Rakesh Saxsena, Compressive review of Control Schemes for battery and Supercapacitor Energy Storage System.
8. Bosco Milseviie, Ivo Uglesic, Inductive Influence of 25 Kv, 50 Hz Electrified Single Rail Traction system, MATEC Web of conferences, MET 2017.
9. M. Marchesoni and C. Vacca, "New DCDC Converter for Energy Storage System Interfacing in Fuel Cell Hybrid Electric Vehicles", IEEE, vol. 22, no. 1, pp.301- 308, Jan. 2007.
10. Q. Zhu, X. Feng, "Application Analysis of On-board Energy Storage Device Based on Super Capacitor Principle," Railway Locomotive & Car, vol. 33, no. 3, pp. 90-94, June 2013.
11. H. Glickenstein, "High-Speed Trains," IEEE Vehicular Technology Magazine, vol. 4, no. 4, pp. 9-14, Dec. 2009.

AUTHORS PROFILE

The author **Ms. Nilam Ganpat Jadhav** received BE. (Electrical Engineering) from Pune university in 2017.she is pursuing ME in power electronics and drive in AISSMS IOIT, Pune. research interest in power electronics drive in traction system. Currently working as lecturer at Government Polytechnic Awasari College in Pune.

The author, **Dr. Shashikant Madhukar Bakre** completed his engineering education -Bachelor of Engineering from Nagpur University, India and Master of Engineering from Pune University, India. He completed management education, – Master of Management Studies from Pune University. He received his Ph.D. from Bharati Vidyapeeth, Pune, India in Electrical Engineering in the year 2011. He has a vast experience of teaching various subjects in Electrical Engineering, Information Technology and Management at the institutions namely Symbiosis Institute of Business Management (S.I.B.M.), Cusrow Wadia Institute of Technology (C.W.I.T.) and Institute for Studies in Technology and Management (I.S.T.M.). He has worked as Superintending Engineer in Maharashtra State Electricity Transmission Co. Ltd. At present he is working as Professor in Electrical Engineering Department at AISSMS IOIT, Pune.

Mrs. Ashpana Shiralkar is a doctoral student in the PhD program in Electrical Engineering at College of Engineering, Savitribai Phule Pune University (SPPU), Pune (India). Her research focuses on robust control of Electro Hydraulic Servo System. Ashpana is Head of Department, Electrical Engineering, AISSMS's Institute of Information Technology, Pune at SPPU. She has total 18 years of teaching experience. She has authored a few peer-reviewed conference and journal papers.

Ms. Nilambari V Devarkar received BE. (Electrical Engineering) from Pune university in 2008.she is pursuing ME in power electronics and drive in AISSMS IOIT, Pune.research interest in power electronics drive in traction system. Currently working as lecturer at Government Polytechnic Awasari College in Pune.

Dr. S. V. Bhangale is a received B.E degree form SSGM Collage engineering of in 1990 & M.E from L.D.college of engineering Ahmedabad, Gujarat university, india in 1993.In 1991 he joined as a lecturer in Department of electrical Enginnering polytechnic, Shahada, india .Now working H.O.D of electrical department in Government polytecnic awasari khurd. He is a member of Institute of Enginners(INDIA),and a life member of indian society Technical education. He is senier member of IEEE.