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A Dynamic Real Time Interphase Power Flow Technique of Railway Platform Rooftop Solar Power Interface with 25 KV Oh Traction

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Abstract

Indian Railways has planned totap 1000 MW solar energy in ensuing five years.500 MW from railway platform roof tops & rest from other official ancillary complexes to supplement traction load. Roof-Top spaces are ample considering long & wide railway platform at stations in India.TSS in railway traction power supply is placed for each 50 to 90 km segment along railway track for UP & DOWN routes. It is possible to design suitable scheme that can be interfaced for direct connection to 25 kV AC system at TSS locations on 4 to 5 average railway platforms from Bhusawal via Jalgaon, PachoraNandgaon, Manmad, Lasalgaon, Niphad, Nashik Road ,Igatpuri&Kasara Stations. Considering roof top area of 1000 to 5000 sq-metre, it is possible to install solar panels which can generate 100 kW to 500 kW.Saving with conventional Energy intake from utility to the tune of 30 to 40 %. It has been physically seen on live train passing that the load varies from few hundred kW to 3 or 4 MW for duration of few seconds to minutes. Neutral sections facilitate balanced loading on all three phases of utility as the phases R, Y & B are loaded in sequence. This paper explores the ever-tried model of direct solar power feed from railway platform rooftops to 25 kV AC tractionsupply using dynamic inter-phase power flow technique in real time with all associated balance of equipment's.

Keywords: RE(Renewable Energy), OHE(Overhead Electric Equipment), IR(Indian Railway).IPH (Inter-phase power flow) IPC (Inter-phase power flow Controller)

INTRODUCTION

Transport mode of Railway network in India comprise 66000 routes of kms of track. So far only 42 % is Electrified. It is one among huge network in the world representing 2nd largest single consumer of electricity. In context of sustainability of Environment with outcomes of Rio De Janeiro conference in 1992 Kyoto COP 3 in 1997 Paris summit in 2015 & latest COP 27 in Egypt protocols to raise funds & compensate underdeveloped & developing nations. Indian Railways have taken initiatives to intercept Green Energy. Vision 2020 document has outlays to utilize 10 % of Renewable Energy. Railways in India consume 2100 MW which amounts to 18 billion units Green Energy has two types to deal with solar thermal & solar phonotactic.Solar photovoltaic resource in subcontinent India has 300 clear sky sunny days in a year & such promising potential of green power around 1000 MW is to be achieved in ensuing five years. To reduce carbon foot-print by focusing on 2nd single largest consumer is right preposition in the days to come. It is therefore imperative to explore the options that facilitate the solar green power to meet the traction load demand directly connecting it to 25 kV AC Power supply system. National Government set an ambitious RE target of 175 GW by 2022 and requested various government agencies to consider deploying solar energy. IR took the leadership role by setting up a 50 MW solar rooftop program, with the primary goal of reducing the cost of energy in the long term Solar PV Source will be alternate energy supply to reduce cost of energy & dependence on utility source as the rate of capacity addition in various state utilities is around 7 % compared to rate of rise in demand to the tune of 11 % every year. Indian grid at present generates 3 lakhs of MW& will need around 9 lakhs of MW by the year 2030.With recent demographic statistics global population now clocking at 800 Cr & next to China India represents 2^{ND} largest populated country in the world. For survival with sustainable development henceforth the viable options are either nuclear or Renewables.

Lot of research work seen in power quality area in traction as in [1] the author has addressed an issue of transients arising out of cyclic load of railway traction. In [2] attempt seen in finding solutions to problems of Green Buildings equipped with solar roof top resources to achieve smooth interface & its operation. In [3] author has elaborated the issues of energy conversion & storage to mitigate the inertia aspect when the small piece meal solar sources are interfaced to big grid utilities. In [4] Model comprises dual single five level inverter with Lee Blank Transformers to cater two single phase loads at 750 V for traction from utilities for the train. Author in [5] explained about power quality issues in distributed Generation in case of railway traction which scales little on drive system of Traction. . Hybrid network with wind source in [6] focus on power quality issues for traction purpose. Energy storage devices yet has limitations of cost effectiveness as seen in [7]. In [8] initiatives by railway institution on green power just made a start but in small scale for auxiliary loads. In [9] SPV interface is illustrated for utility approach. Impact assessment of roof top solar is studied by author in [10]. Transients while auto passing high speed railway along neutral section is addressed in [11]. Solar energy integration with storage system is again seen explained by author in [12]. In [13] SPV integration in African Railways yet describe DC to Dc interface as seen in paper [14] Power quality issues due to tiny capacity posing problems of synchronous inertia i.e rate of change of frequency [15]. Hybrid topology as discussed in [16] again rests with DC-to-DC interface. High speed multiple units [17] applications provide solutions to load side but not the source side from green power interception. Qualities issues are well narrated in [18] yet seen the secondary when compared to dynamic interface to traction load using IPC Technique. Auto passing mitigates the switching complexities of train pantograph at neutral section as explained in [19]. Co phased Traction power system is yet based on traditional matured utility services [20]. Impact of SPV systems is discussed in [21] for which steps are in offing to mitigate issues like synchronous inertia in utility grids. In [22] My paper published stating the proposed idea & further work is progressed now with this paper.[23] In this paper, a novel hybrid algorithm based on grey wolf optimizer (GWO) and artificial bee colony (ABC) algorithm called GWO-ABC is proposed to inherit their advantages and overcome their drawbacks[24] In this paper A systematic strategy for optimizing the controller parameters along with scaling factors and the antecedent MF parameters for minimization of performance metric integral time absolute error (ITAE) is presented.[25] This research study presents the nonlinear fractional order PID (NL-FOPID) controller for 5-DOF redundant robot manipulator for joint trajectory tracking task.[26] The aim of this paper is to compare the performances of new fuzzy fractional order (FO) PID (fuzzy $PI^{\lambda}D^{\mu}$) controller with integer order fuzzy PID and PID controllers for controlling redundant robotic system for trajectory tracking problems.[27] This paper presents a simple design and parameters tuning approach using multi-objective optimization of two-degree of freedom fractional order proportional-integralderivative (2-

DOF-FOPID) controller applied to magnetic levitation system [28] This paper presents a multi-objective robust design and parameters tuning approach of two-degree of freedom fractional order proportional-integral-derivative (2-DOF-FOPID) controller applied to MLS.[29] In this paper, newly proposed hybrid grey wolf optimizer and artificial bee colony algorithm (GWO-ABC) is applied for parameter optimization of a fractional-order fuzzy PID (FO-FPID) controllers for trajectory tracking problem applied to two-link robotic manipulator with payload.[30] This paper proposes a reference point based controller tuning approach to include the designer's preference in multi-objective optimization (MOO) procedure.

This paper is organized as: - Sec II comprising Technoeconomic feasibility &simulation results & hardware experiments based on actual to 132 kV Utility Substations Railway Traction Substations Neutral Section of Railway Track etc.Sec III elaborates Experimental set ups Sec IV covers existing set up of Utility power supply to Railway Traction Section V Discusses Interface Technique viz..IPC for direct Solar power interface to 25 kV AC Traction & the last section VI concludes the remarks on proposed paper..

TECHNO-ECONOMIC FEASIBILITY

Indian Railways has to spend huge payouts forenergy consumption towards traction load besides their staff wages pensions etc.. Optimizing energy costs is prime concern for railways Indian railway pays Rs 6 to 7 per unit of electricity consumed. It is dependent on state DISCOM’s who charge more than their Agro Industrial or commercial consumers. Again the universal obligation of reducing carbon footprint suggests to maximize using clean green power like solar for consumer like traction Railway has sufficient potential to utilize space on track siding as well as platform rooftops It is technically feasible to utilize Average 4 platforms (650 meter length facilitating 650 x 20 = 13000 sq-metre Area) on each Railway stations such as Bhusaval, Jalgaon, Pachora, Nandgaon, Manmad, Lasalgaon, Niphad, Nashik Road, Deolali, Igatpuri&Kasara platform roof tops generating 100 to 200 kW solar power & then interface it directly to 25 kV AC OHE system of traction. It is seen on practically visiting Igatpuri 132 kV EHV station of MSETCL that a commuting train at just rolling state draws 13A i.e. 325 kW on 25 kV side & further the load increases to 250A consuming 6.25 MW. It implies that solar penetration can save utility conventional power intake by 30%.to 40 %.

Two Traction Transformers as shown in figure 1 were viewed as welding transformers & loaded with water load to get drooping characteristics with water load. It is seen that the voltage varies from 50 to46 volts at current from 0A to80A as shown in Table 1.In next attempt phase angle in secondary phase was checked with respect to primary as 60 degrees and with respect to neutral it implies that the angle between phasors will be 120 degrees as per figure 2.

TABLE I. TRANSFORMERS VOLTAGE VARIATION WITH LOAD

Sr. No.	Transformer 1		Transformer 2	
	Load Amps	Voltage	Load Amps	Voltage
1	0	45.6	0	50
2	15	45.6	15	49.5

3	30	34.3	30	49
4	48	34.2	48	47.5S
5	60	34.5	60	46.9
6	65	34.7	65	46.7
8	80	34.3	80	46

Fig 1: Experimental Set-up

Fig 2: Experimental results which shows phase shifts

EXPERIMENT USING TWO PT'S AS TRACTION TRANSFORMERS

On 11th Nov 2021 Set-up of Two PT's 440 / 110 volts AC was arranged with DSO to evaluate the voltage difference & phase angle between secondary phases. Initially Primary side was fed with RY phases to both & output seen at secondary. It was observed that the phase angle was zero as Waveforms seen overlapping each other as synchronized phases & the voltage between phases zero when checked with multimeter. This attempt ensured healthiness of wiring setup.

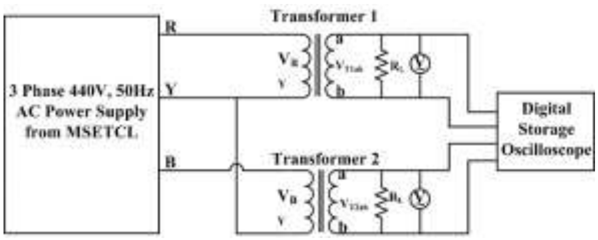

Fig. 3: Hardware Setup for Measuring phase angle & Magnitude between Line Voltages of two transformers

On 13th Nov 2021 an experiment was performed in GESCOE Nashik College workshop connecting Two PTs to R & Y 440 Volts as primary supply. Y phase was given common to one terminal of both PT's. Secondary terminals were connected to DSO to observe waveforms It was observed that the voltage between phases were 108 volts & the angle as 64 degree against 3.6 msec scale on DSO. Further one common terminal of secondary was grounded & voltage between phases seen reduced to 64 volts i.e 108/1.732 (Root Three). It was therefore inferred that the phase angle is 60 degrees between secondary phases & voltage measured as 110 volts meaning that in actual traction system the phase anglewill be 60 degree & phase voltage difference as 25 kV.

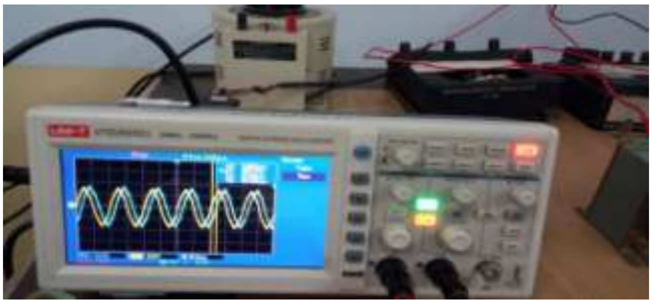

Fig.4: Phase angle between primary & secondary phase

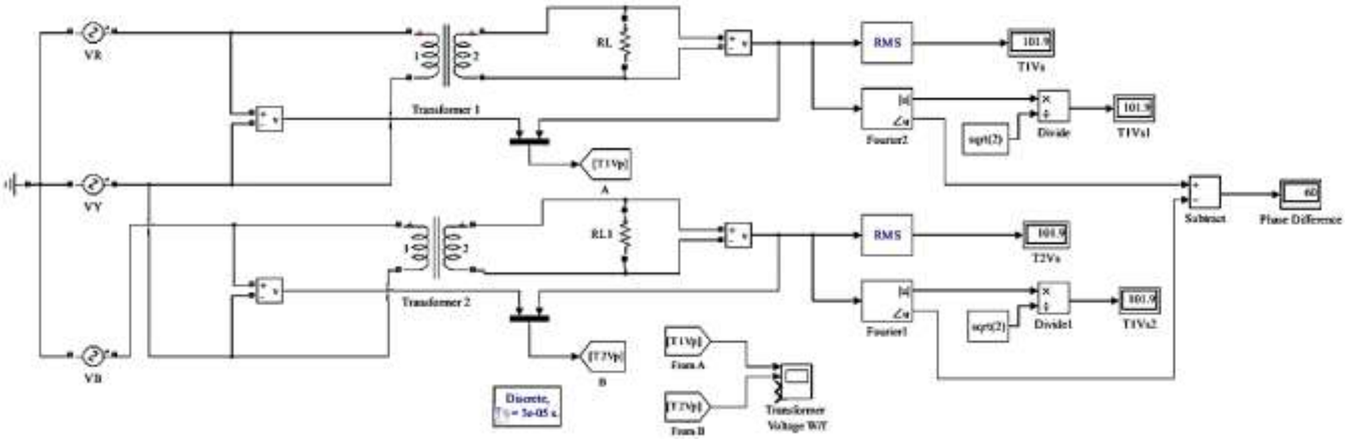

Fig. 5: Simulink Model for the experimental Setup which validate the result

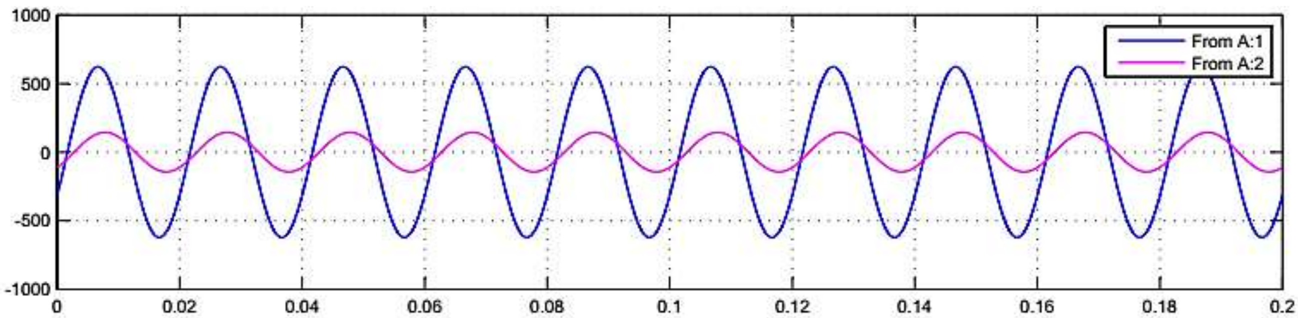

Fig. 6: Transformer 1 primary & secondary voltage waveforms

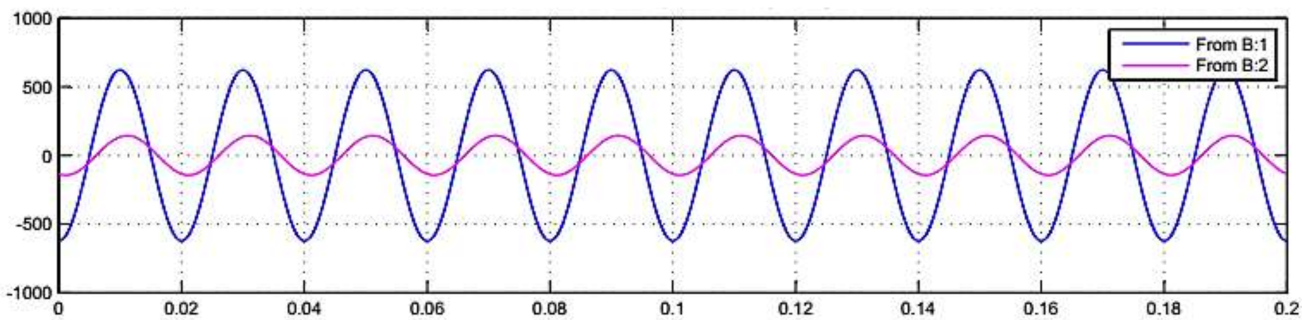

Fig. 7: Transformer 2 primary & secondary voltage waveforms

The experimental results are validated with the help of MATLAB simulation. Figure 5 shows the MATLAB Simulink model setup for measuring the phase angle difference between Transformer 1 & Transformer 2. The Fig 6& Fig 7 shows the primary and secondary output voltage waveforms of Transformer 1 & Transformer 2 respectively. The above results therefore again inferred that the phase angle is 60 degrees between secondary phases of both the transformers.

PRESENT PHASE DISTRIBUTION FROM UTILITY FOR RAILWAY TRACTION

On 16th Nov 2021 Railway Traction supply from Utility sources Viz. .MSEBfrom Igatpuri via..220 kV OCR (RY Phase) ..132 kV Lasalgaon (RY Phase) ..220 kV Manmad (RYPhase) ..132 kV Pimpharkhed (RY) ..132 kV Chalisgaon (RB Phase) ..132 kV Pachora (RB Phase) ..220 kV Bhadli (RY Phase) ..132 kV DeepnagarBhusawal (RY Phase) as shown in Fig 8 below.

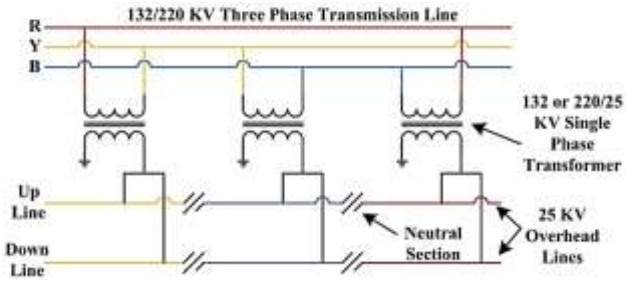

Fig.8: Schematic diagram of 25 kV overhead Traction lines

Concept of one sun one Traction & one Nation can be realized if the railway platform roof top solar power interface succeeds synchronous operation at railway stations with set of suitable retrofits of IPC or PST utilizing ZCD or PLL systems.

IPC Interface logic diagram of present phase distribution from utility for Railway Traction is as shown in Fig.9 below.

OVERHEAD RAILWAY TRACTION SOLAR INTERFACING TECHNIQUE.

Interphase power flow facility will reinforce the power utility optimization as train leaving neutral section will need strong source to bear with the acceleration because by then the mass momentum of train would have died own being in coasting &retarding operation mode. It will also improve power quality & stability to ride over cyclic nature of traction load.

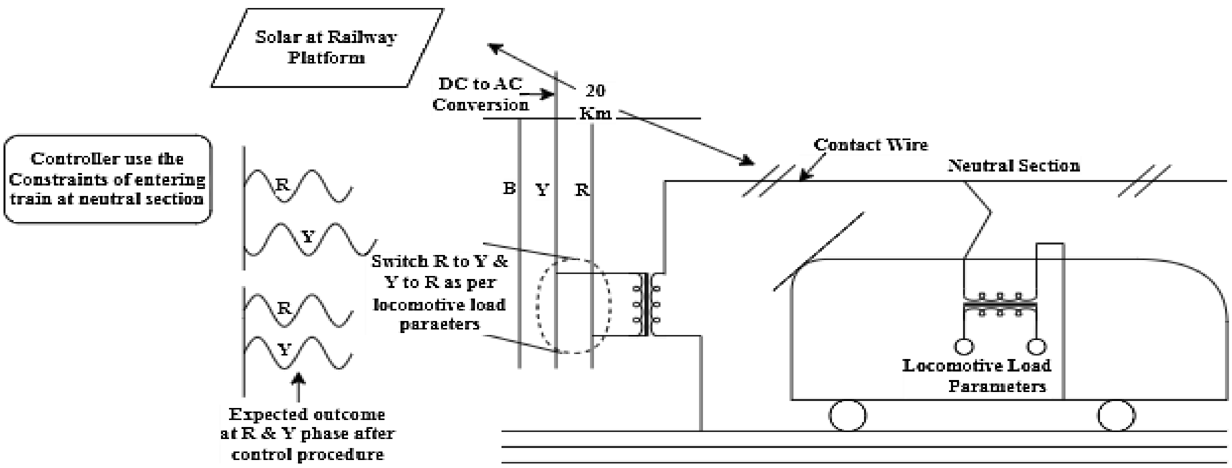

Fig 9 IPC Logic Diagram

On 17th ofNov 2021 Simulation on MATLAB was tried selecting 440 / 110-voltPT's & confirmed that the physical measurements above are correct & with proper interfacing components values it is possible to import or export the solar power to adjacent sides of neutral section depending on the loading on that section. Interphase power flow will optimize the solar source utilization to its fullest measure.

CONCLUSION

The phase angle & voltage difference in adjacent traction overhead phases were physically checked in Two PT Model of 440 / 110-volt AC rating.

Practical set up was obtained from The Testing Engineer of Railway Bhusawal& confirmed that @ 60-degree angle is set on relays to protect against faults.

Thus, it was possible to check magnitude & phase angle of secondary phasor using PT's 440 / 110 volts AC for primary & secondary as analogous to 132 / 25 kV Railway Traction. This is necessary to ensure the synchronizing of neutral bus sections in R, Y or B Phases when Train Travels via neutral sections along the overhead Traction line. Solar power from Railway Platform Roof-Top can be Interfaced at Railway station itself to 25 kV AC Catenary & Corresponding Generation via data logger can be sensed for that much Generation from either side of neutral section dynamically in real time R to Y, Y to B or B to R

Having observed above fact on DSO waveforms the angle measured is 60 degrees & voltage as 110 volts as such both aspects seem validated with the help of MATLAB Simulations too.

REFERENCES

1. Radovan Dolecek, Ondrej Cerny, Zdenek Nemec and Jan Pidanic,"TheBehaviorofthe Traction Power Supply System of AC 25KV 50Hz During Operation",addressingtransients Springer International Publishing AG,2017.
2. Neel Mathews, Narendar Rao, Gowrisankar and Biswajit Pattnaik,\GridtiedRooftop solar: Problems, learnings and solutions", First International Conference onSustainable Green Buildings and Communities (SGBC), Dec. 18-20, 2016.
3. Hitoshi Hayashiya, Shinya Kikuchi, Kazushi Matsuura and Masami Hino,\Possibilityof energy saving by introducing energy conversion andenergystoragetechnologiesintraction power supply system", 15thEuropean Conference on Power Electronics and Applications (EPE), Sep. 2-6, 2013.
4. Ming Meng1*, Yaning Yuan1, Mingwei Guo1, Li Jiang2, Jian Liu2, Dalong Hu2, Haiyang Cong3, and Dan Hao4, (2014). A Novel DC Microgrid Based on Photovoltaic and Traction Power Supply System, IEEE Conference and Expo Transportation Electrification Asia-Pacific (ITEC Asia-Pacific)
5. Weijie Pan, Surya ChandanDhulipala and Arturo SumanBretas, (2017). A Distributed Approach for DG Integration and Power Quality Management in Railway Power Systems, IEEE International Conference on Environment and Electrical Engineering.
6. LaxmanSingh;ChandanVaishnav;Vivek Shrivastava, (2016). Performance Analysis of Hybrid Network of Indian Traction Power System using Renewable Energy Sources, International Conference on Micro-Electronics and Telecommunication Engineering (ICMETE)
7. Satoru Sone, (2010). Improvement of traction power feeding/ regeneration system by means of energy storage devices, Electrical Systems for Aircraft, Railway and Ship Propulsion

8. “International Conference on Green Initiatives & Railway Electrification", Institution of Railway Electrical Engineers, Ministry ofRailways,GovernmentofIndia,Oct27-28, 2017.
9. Ashutosh V Pailwan, Indranil Chatterjee and K. Rajamani, \Roof Top PhotovoltaicGridIntegration:Utility Approach", International ConferenceonElectricalPowerand Energy Systems (ICEPES), Dec. 14-16, 2016.
10. Kalpesh A. Joshi and N. M. Pindoriya, \Impact investigation of rooftopSolarPVsystem: A case study in India", 3rd IEEE PES Innovative Smart Grid TechnologiesEurope (ISGT Europe), Oct. 14-17, 2012.
11. Qian Wang, Jun Lu, Qingfeng Wang and Jiandong Duan, “Transient overvoltagestudy of auto-passing neutral section in high-speed railway",IEEETransportationElectrification Conference and Expo, Asia-Pacific(ITECAsia-Pacific),Aug.7-10,2017.
12. Abhishekh K. Singh, Amitabh Sinha , Asheesh K. Singh&R. Veeraganesan, (2016). Solar PV fed Grid Integration with Energy Storagesystem for Electric Traction Application” 10th. International Conference on Intelligent Systems and Control (ISCO).
13. Hitoshi Hayashiya, Shinya Kikuchi, Kazushi Matsuura, Masami Hino, MasateruTojo, Tetsuya Kato, (2013). Possibility of energy saving by introducing energy conversion and energy storage technologies in traction power supply system, 15th European Conference on Power Electronics and Applications (EPE) France.
14. M. J. Lencwe;S. P. Chowdhury;H. M. ElGohary, (2016). Solar Photovoltaic Integration on Locomotive Roof Top for South African Railway Industry, 51st International Universities Power Engineering Conference (UPEC).
15. MohamedRageh,AugusteNdtoungou, AbdelhamidHamadi and Kamal Al-Haddad , (2018). Railway Traction Supply with PV integration for Power Quality Issues, 44th Annual Conference of the IEEE Industrial Electronics Society.
16. Ming Meng1*, Yaning Yuan1, Mingwei Guo1, Li Jiang2, Jian Liu2, Dalong Hu2, Haiyang Cong3, and Dan Hao4, (2014). Hybrid Bidirectional Interactive DC Traction Power Supply System with Microgrid ”IEEE Conference and Expo Transportation Electrification Asia-Pacific (ITEC Asia-Pacific).
17. Kenji Sato, Masakatsu Yoshizawa, and Takafumi Fukushima, (2010). Traction Systems Using Power Electronics for Shinkansen High-speed Electric Multiple Units, International Power Electronics Conference - ECCE ASIA.
18. YevgenSokol; VolodymyrZamaruiev; VolodymyrIvakhno; BohdanStyslo, (2018). Improving the Quality of Electrical Energy in the Railway Power Supply System, IEEE 38th International Conference on Electronics and Nanotechnology (ELNANO).
19. Qian Wang; Jun Lu; Qingfeng Wang; JiandongDuan, (2017). Transient Overvoltage Study of Auto-passing Neutral Section in High-speed Railway, IEEE Transportation Electrification Conference and Expo, Asia-Pacific (ITEC Asia-Pacific).
20. Fulin Zhou; Qunzhan Li; DaqiangQiu, (2010). Co-phased traction power system based on balanced transformer and hybrid compensation, Asia-Pacific Power and Energy Engineering Conference.
21. Kalpesh A. Joshi; N. M. Pindoriya,(2012). Impact Investigation of Rooftop Solar PV System: A Case Study in India,,3rd IEEE PES Innovative Smart Grid Technologies Europe (ISGT Europe).

22. Nagesh S Pande;Dr Atul R Phadke;Dr Prashant Gaidhane; Connection & Control Strategy for Direct Injection of Railway Platform Roof-Top Solar Power in to Traction Network Vol 16 No 10 2021 PP.65-72 ISSN 2456-3463 International Journal of Innovations in Engineering & Science.
23. A hybrid grey wolf optimizer and artificial bee colony algorithm for enhancing the performance of complex systems Dr PJ Gaidhane, MJ Nigam Journal of computational science 27, 284-302 66 2018
24. Design of interval type-2 fuzzy precompensated PID controller applied to two-DOF robotic manipulator with variable payload PJ Gaidhane, MJ Nigam, A Kumar, PM Pradhan ISA transactions 89, 169-185 48 2019
25. A nonlinear fractional order PID controller applied to redundant robot manipulator A Kumar, PJ Gaidhane, V Kumar 2017 6th International Conference on Computer Applications In Electrical …16 2017
26. Optimal design of fuzzy fractional order PIλDμ controller for redundant robot A Kumar, V Kumar, PJ Gaidhane Procedia Computer Science 125, 442-448 14 2018
27. Tuning of two-DOF-FOPID controller for magnetic levitation system: A multi-objective optimization approach PJ Gaidhane, A Kumar, MJ Nigam 2017 6th International Conference on Computer Applications In Electrical …8 2017
28. Multi-objective robust design and performance analysis of two-dof-fopid controller for magnetic levitation system PJ Gaidhane, MJ Nigam 2017 14th IEEE India Council International Conference (INDICON), 1-6 2 2017
29. The Enhanced Robotic Trajectory Tracking by Optimized Fractional-Order Fuzzy Controller Using GWO-ABC Algorithm PJ Gaidhane, S Adam Soft Computing: Theories and Applications, 611-620 2022
30. Connection and Control Strategy for Direct Injection of Railway Platform Rooftop Solar Power into Traction Network DPJG Nagesh Pande , Dr. Atul Phadke International Journal of Innovations in Engineering and Science 6 (10), 65 - 72 2021
31. Preference Oriented Multi-Objective Optimization for Tuning of Controllers: A Reference Point Based Approach PJ Gaidhane, MJ Nigam 2019 5th International Conference on Signal Processing, Computing and …2019