IJDI-ERET

INTERNATIONAL JOURNAL OF DARSHAN INSTITUTE ON
ENGINEERING RESEARCH AND EMERGING TECHNOLOGIES
Vol. 11, No. 2, 2022
www.ijdieret.in

(Research Article)

Future Applications of Multilevel Inverter in Short Circuit Alternator for the Control of Shaft Voltages and System Harmonics

Arun Kumar Datta[1*]

[1]Central Power Research Institute, Bhopal, MP, INDIA*

Abstract

Static drives are being used invariably in all rotating machines nowadays, in spite of its several ill effects. Other than harmonics generation shaft voltages are also prime concern for bearings in the machines connected with static drives. This paper has done research on a 1500 MVA alternator being used for testing of electrical equipment. Model of this alternator and its drives are simulated with real time parameters. Built model is validated and further analysis is carried out by drawing waveforms and frequency spectrums. High levels of harmonics in power circuits and shaft voltages have been observed in the present system. A multilevel inverter (MLI) has been proposed in the drive of this machine replacing conventional current source inverter to control the harmonics and shaft voltages.

Keywords: Alternator, current source inverter, common mode voltage, THD, static frequency converter, multilevel inverter.

1. Introduction

A specially designed 1500 MVA synchronous machine feeds the energy required during short circuit tests on electrical power equipment. Synchronous machines have many excellent features though starting problem has made its use for limited purposes components. By virtue of modern static drives presently it is being used in a widespread manner. After the invention of semiconductor devices various static starting devices for synchronous motors are developed. These devices named ASD, VFD etc. are boon to the motor technology. Among them the thyristor converter has firmly established as the static electrical power conversion equipment of many types ranging from a few hundred watts to tens megawatts. Though the concept of frequency converter is very old but for the large electric machines this soft starting technology is thought of at a later stage. Under the static drive technology Static Frequency Converter (SFC) is envisaged, designed and applied on many large machines [1] - [3]. Uses of SFC has increased in the recent years in the field of aviation industry, computer installations, communications, military installations, motor speed control, ships and power transmission. The 1500MVA synchronous machine taken as study object in this paper is driven with SFC. This machine is a normally a very high power generator for short time rating. Usually a motor is used as a prime mover for this type of alternator. But this one is without a prime mover and the machine itself rotates as a motor; thereafter converted to generator to deliver the energy for short circuit tests [4], [5].

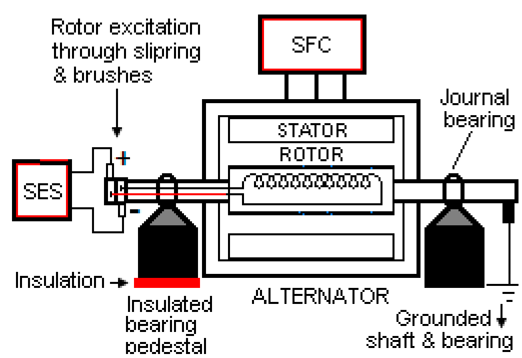

Figure 1. Alternator rotor supported with two bearings (insulated EE and grounded OEE).

Presence of shaft voltages and occurrences of electric discharge machining (EDM) is observed in the bearing of this machine. Electric discharge machining (EDM) is one type of bearing current flows from the charged shaft to the ground through bearings or other metallic parts. Study was carried out to find out the reason of accumulating charges on the shaft of short circuit alternator. The weight (approx. 40 ton) of rotor of short circuit alternator is supported with two journal bearings at the both ends (Figure 1). Exciter end (EE) bearing of short circuit alternator is insulated but the opposite exciter end (OEE) bearing is at ground potential. To keep the shaft at ground potential, grounding brushes are placed on the shaft at opposite exciter end. Electric sparks have been observed in the

*[*]Corresponding Author: e-mail: akdattabpl@gmail.com,
Tel-+91-9425371370*
ISSN 2320-7590 (Print) 2583-3863 (Online)

grounding brushes. This is called shaft discharge current or EDM [6]. Discharge current pulses contain high amount of energy and it is the prime source of bearing & shaft erosion. EDM can be measured with fast response waveform recorder. Alternator shaft grounding system and one EDM recording is produced in Figure 2.

Common mode voltage (CMV) [7] is another phenomenon observed in the inverter power output for a machine. This non-zero parameter is the neutral point voltage equals to the average sum of instantaneous values of 3-phase inverter output. CMV is also one of the responsible elements to induce shaft voltage through parasitic capacitances. Various inverter topologies claim to minimize the CMV [8]-[10]. Where inverter topology cannot be changed, in that places CMV can be filtered out with different filtering techniques such as active, passive and hybrid [11]-[13].

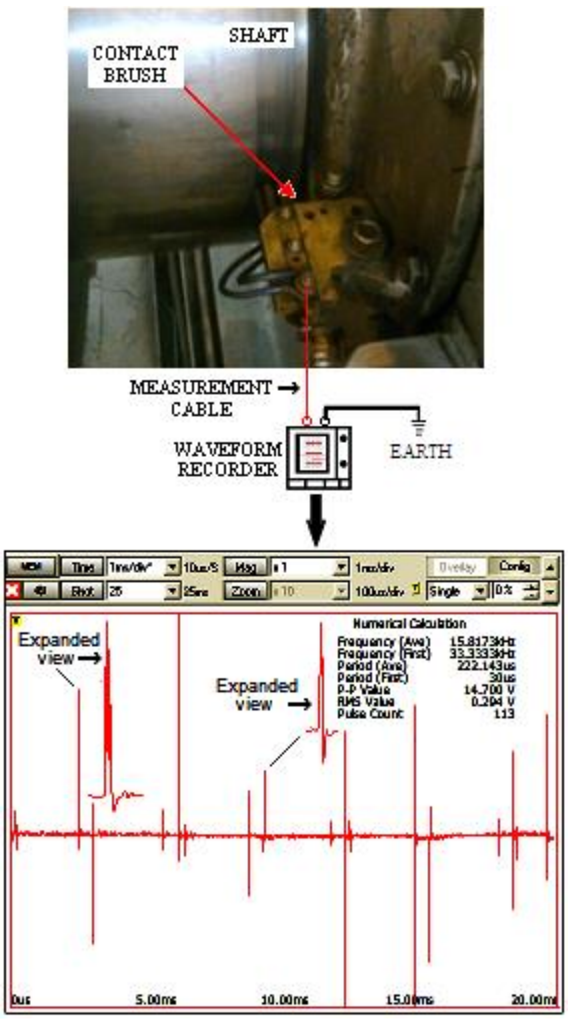

Figure 2. Shaft grounding system and EDM measurement.

The SFC in this machine is a current source inverter (CSI) [14]. Power quality study of this system is done and explained in literature [15].

Multilevel inverter (MLI) is one of the best solutions for the problem discussed so far [16], [17]. In multilevel inverters depending upon the inverter level and type of modulation, several voltage levels are added to each other to create a smoother stepped waveform which is near to sine wave. This concept is originated [18] in year 1975 and since then it is used to control harmonics and CMV in the inverter output. Through software simulation, effects of MLI have been studied in this short circuit alternator system.

For further investigation MATLAB/Simulation techniques are used on this machine and its supply source. Reduction in shaft voltages and THD level has been envisaged with the proposed adoption of multilevel inverter (MLI) in the SFC drive.

2. Short Circuit Alternator and Associated Systems

Healthy power system is need of the day. For uninterrupted power supply, utilities must employ good quality equipment. Hence all power system equipment must pass through some stringent quality tests before putting them into service. Short circuit is one of the mandatory type tests conducted under the most severe conditions. It is performed to prove the equipment's ability to withstand the severities under the condition of actual short circuit fault. Energy requirement during short circuit test is enormously high and equals to equipment's fault level. Normally these tests require a stable source with high fault power level. A specially designed high power three phase alternator is best suited for this purpose. Figure 3 shows the single line diagram for conducting short circuit test with an alternator as high power source. The alternator is connected with two static sources; SFC at the stator terminals and static excitation system (SES) at the rotor side (Figure 4).

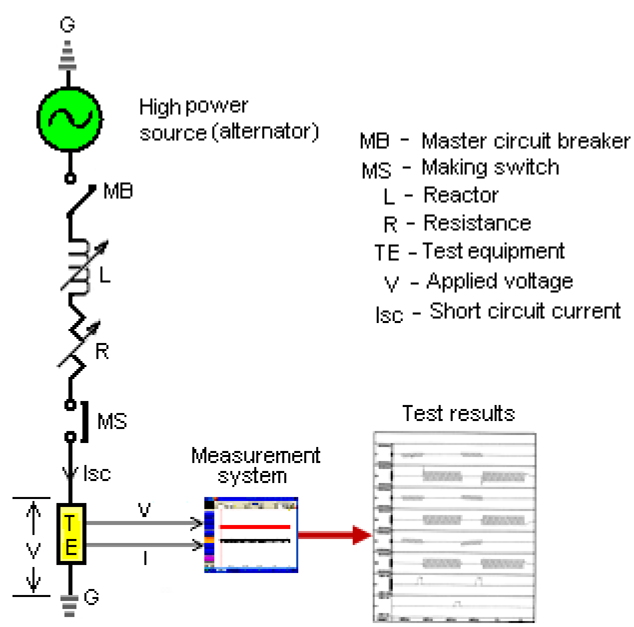

Figure 3. Alternator with short circuit test circuit.

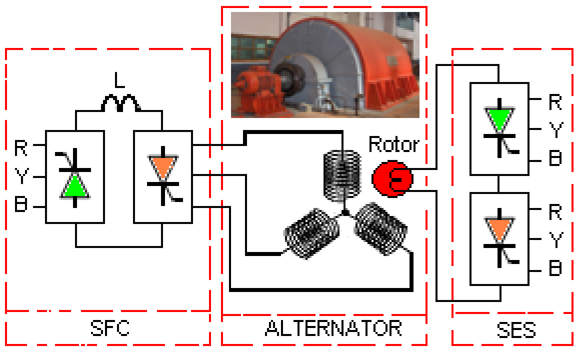

Figure 4. Block diagram of short circuit alternator with SFC and SES.

AC to AC conversion with an intermediate DC link reactor is most popular [19], [20] among the various static drives. In this category high rating thyristor based static drives called SFC is in use worldwide for large machines in pump storage power plant, electric locomotive and gas power plant [3], [21] - [24]. It was a novel idea to implement the SFC technology to run the alternator used in short circuit testing of electrical equipment [25]. To reduce the load on the source and to ease the starting process in large machine, frequency conversion takes place in SFC from a very low value up to the rated value [26]. Short circuit alternator starts up as a motor thereafter converted to generator to deliver electrical energy required during the test. Details of these operations are explained in literatures [4], [25] and [26]. SES is basically a poly-pulse AC-DC converter. To improve the input power factor and to reduce the harmonics level, SES is designed as a 12-pulse thyristor based controlled DC source [27].

3. System Description

The schematic of drive (SFC) for the short circuit alternator is shown in Figure 5. The source power is drawn from the grid at 33kV level. It is stepped down to 1.72kV level, the operating voltage of SFC in this system. Hence it is a three stage process. In the first stage, AC power frequency is converted to DC power with a six pulse phase-controlled rectifier known as network bridge (NB). It is controlled in such a way as to produce a unidirectional current of controllable magnitude in smoothing inductor. Smoothing reactor filters out the ripples from the DC current in the second stage. In the third stage this current is then switched in a thyristor inverter called machine bridge (MB) to provide variable frequency three phase current to a synchronous motor. MB produces three-phase alternating current, the frequency of which is varied from a very low value up to the nominal value [25]. MB thyristors are operated in such a way that at any time one top thyristor and one bottom thyristor must be conducting, ensuring that thyristors in the same leg never be conducted at the same time to avoid short circuit [28]. Most of the time line side converter acts as rectifier and machine side as inverter. If required they can also reverse their role in need of re-generative braking [29]. Thus, full four-quadrant operation of the drive is possible. The inverter gives variable voltage variable frequency output to the load i.e. the machine here. Basically rectifier sets the DC link current to the desired level by varying the firing angle and inverter provides frequency control [30]. Theoretically outputs wave shapes of these kinds of inverters are rectangular in nature. With these features of SFC, the machine can be operated in dual mode i.e. motor and generator. Thyristor firing angle in the NB and MB are set by SFC controller with various feedback loops (Figure 5). This controller is popularly known as power electronic controller (PEC) which acts very fast in µsec range during short circuit test sequence [21].

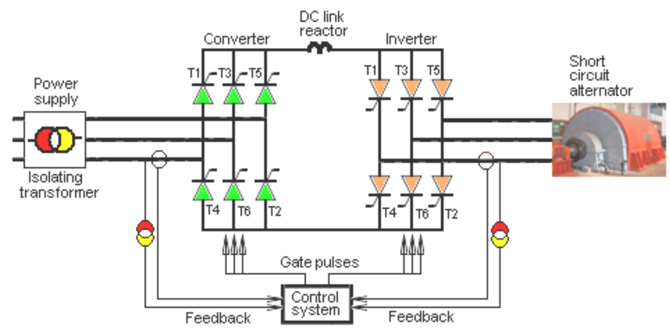

Figure 5. Schematic of static drive for short circuit alternator.

4. System Modelling

To analyse harmonics profile and to find out the root cause of EDM, thorough investigations is done on the present system on MATLAB/Simulink platform [4] [31]. Required parameters and waveforms were taken from the actual system. The investigation work on the system was done thoroughly by simulation technique. Model of the existing system is created (Figure 6) with the data (Table 1) drawn from the working system. In Simulink model, one three phase source, one step down transformer, two thyristor bridges are taken [32], [33]. A reactor is placed in between the two bridges. Step down transformer is inside the rectifier block. Rectifier and inverter both are in six pulse configuration.

Table 1. SFC model parameters

Parameter	Value
Input source	33 kV, 3-ph
Transformer nominal power	3.5 MVA
Transformer primary input, Delta	33 KV, 50Hz
Transformer secondary output, Star	1.72 KV
Thyristor bridge	3 arms
Snubber resistance	2000 Ω
Snubber capacitance	0.1 µF
Link reactor	4.8 mH
Base voltage	12 kV
X/R ratio	20

Motor voltage	1.72 kV
3-ph S.C. level at base voltage	1500 MVA

After running the model various waveforms are plotted. For validation of the model, simulated waveforms are compared with the waveforms from the actual system recorded with a high speed recorder. Machine voltage and current from the simulated and actual system are depicted in Figure 7 to Figure 10, which are found to be similar in nature. Common mode voltage at the machine terminals is also measured with additional measurement and display blocks.

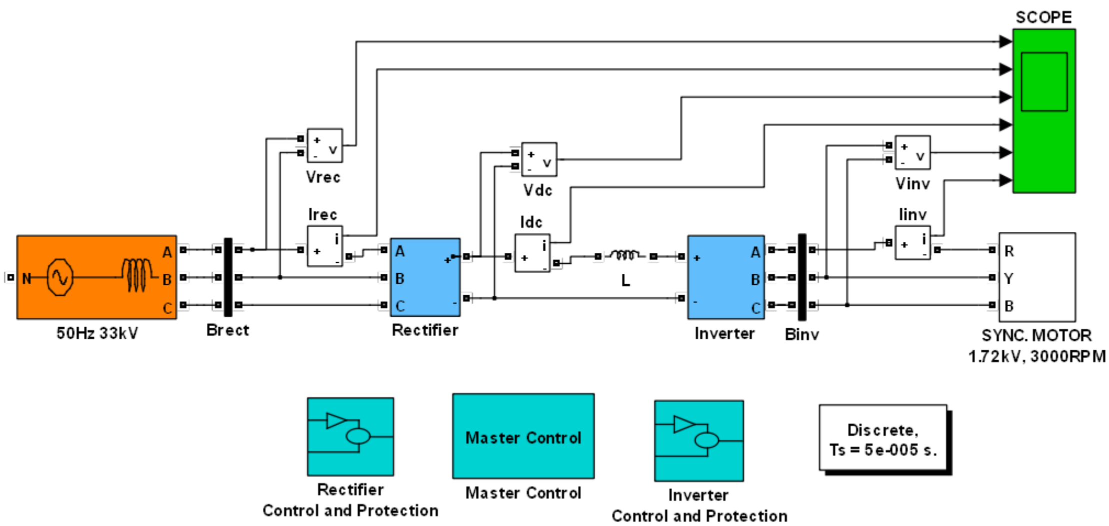

Figure 6. Simulink model of existing system.

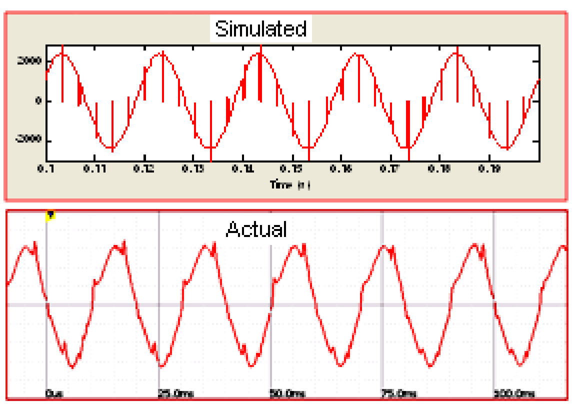

Figure 7. Machine voltage.

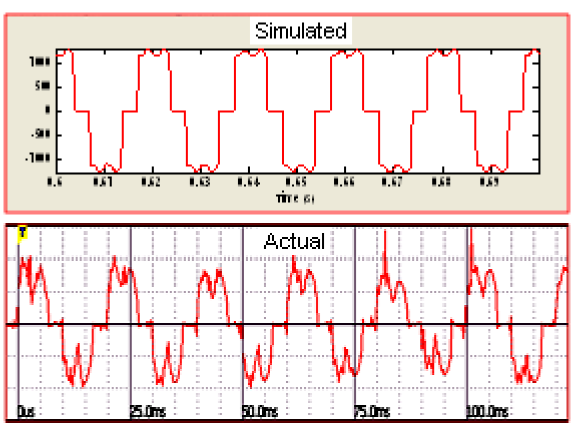

Figure 8. Machine current.

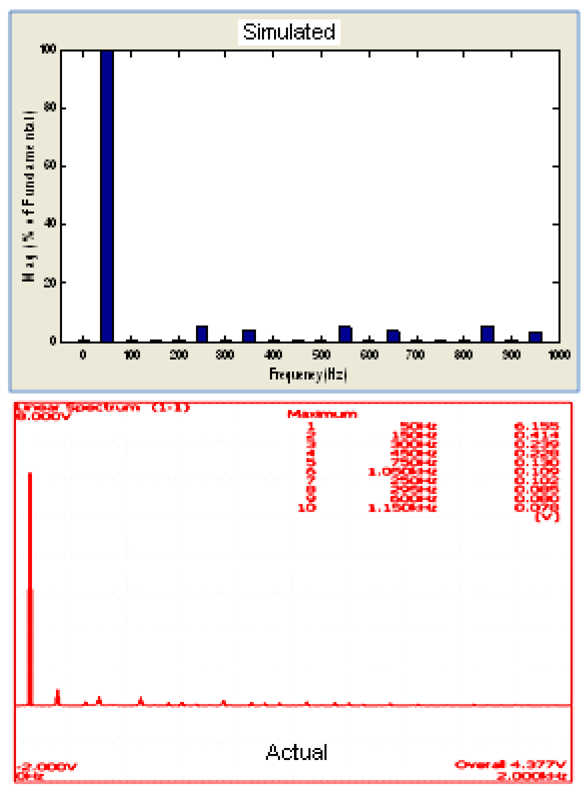

Figure 9. Frequency spectrum of machine voltage.

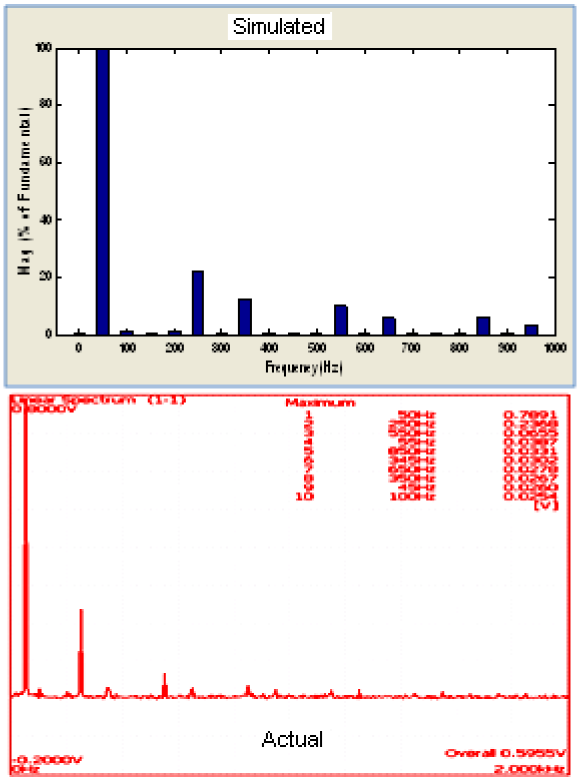

Figure 10. Frequency spectrum of machine current.

4.1 Origin of Shaft Voltage: After the evaluation of machine voltage and current through simulation it is found that voltage contains 20.74% THD whereas; current harmonics is around 30.11%. CMV is measured as 52.18 Vrms. Inverter output voltages contain steep steps (high dv/dt) from thyristors commutation. Stator windings get high frequency switching pulses along with high level of harmonics. Similarly rotor winding also gets a pulsating dc from SES [34], [35]. This dc waveform also contains numbers of high level harmonics and high frequency voltage spikes. The complete short circuit alternator system (SFC, SES and machine) are coupled to each other through distributed capacitances due to these high frequency distortions in stator and rotor windings. Capacitance is formed whenever two charged bodies are separated by a dielectric medium. Winding insulation, air and lubricating oil work as dielectric medium for forming the capacitances in the machine and its drives. These capacitances (also called parasitic capacitances) form between stator to ground, stator to rotor, stator to shaft, rotor to shaft, bearing to ground, cable to ground and also supply source to ground. This bonding is also getting stronger with the increase in frequency, as $X_c=1/2\pi fC$. Leakage current (I_c=C.dv/dt) flows all along the stator and rotor windings due to the parasitic capacitance C and high dv/dt. A high frequency flux is generated because of this leakage current. Harmonics and other high frequency spikes in the stator and rotor power supply also generate high frequency fluxes. These total fluxes link with winding, core, frame, shaft, and other metallic parts. In this way the inductive coupling is formed. Symbolic representation of the capacitive and inductive couplings in the whole system is shown in Figure 11.

Capacitive and inductive couplings together create a cumulative effect for generation of shaft voltages for this long shaft machine.

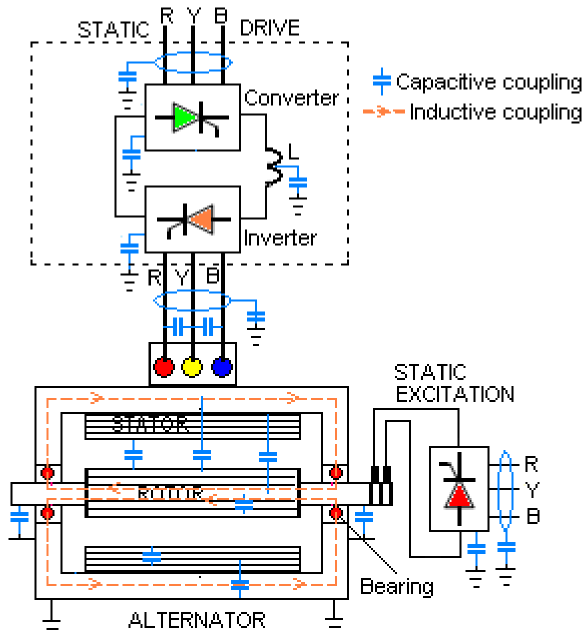

Figure 11. Capacitive and inductive couplings in the system.

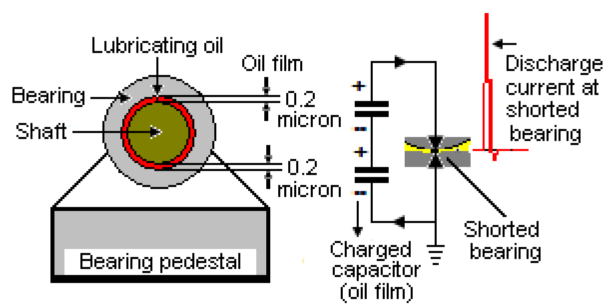

Figure 12. Representation of shaft as the charged capacitor.

4.2 Shaft Discharge Current: As illustrated in Figure 12, in the presence of shaft voltage, it behaves like a charged capacitor. Here surrounded lubricating oil in the bearing shell acts as the dielectric medium. The machine under investigation has insulated bearing at the exciter end and the non-exciter end bearing & shaft are grounded. Flow of circulating current is negligible due to one end insulated bearing. During high speed rotation it is not possible to keep the shaft always at ground potential. Whenever the contact resistance of the grounding brushes is high (due to poor contact or contamination), the dielectric (oil film) breakdown takes place between shaft & bearing due to close proximity or high voltage. This creates a short duration, high peak impulse current from the shaft to the grounded bearing. This is the origination of shaft discharge current or EDM as measured earlier.

The discharge current pulses contain high amount of energy which is the prime source of bearing & shaft erosion. If due care is not taken, this EDM can damage bearing, shaft and other metal parts. Examples of pittings on a journal shaft of a machine are shown in figure 13. EDM also creates electromagnetic interferences in the neighbouring electronic circuits [36].

Figure 13. Pitting on the shaft and bearing of a short circuit alternator.

5. Application of Multilevel Inverter in Existing System

To restrict EDM it is necessary to limit the shaft voltage which is the consequences of electrostatic and electromagnetic couplings in the machine. These couplings are directly depends on the harmonics and common mode voltage level at machine terminals (i.e. at the inverter output). It has already been said that shaft voltage mainly depends on the wave shapes of the voltage applied on the machine. For a sinusoidal supply, amplitude of generated shaft voltage is subsequently low and that can easily be controlled. But wave shapes from the modern static drives is no more sinusoidal rather it contains number of harmonics and high level of CMV. By modifying these sources shaft voltage can be restricted. Amongst the various solutions, PWM multilevel inverter (MLI) is the best one to get a waveform near to sinusoidal [37], [38]. MLIs have been implemented here with the simulation techniques by replacing the existing current source inverter (CSI).

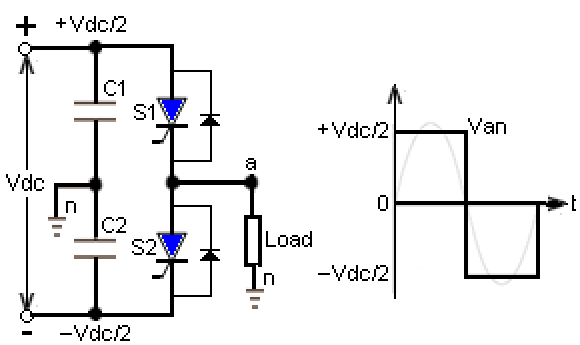

Figure 14. Representation of 2-level inverter.

5.1 2-level PWM Inverter: 2-level inverter can create two different output voltages for the load, $\frac{Vdc}{2}$ or $-\frac{Vdc}{2}$ as displayed in Figure 14. To cater the problems of harmonics and CMV in a simple square wave inverter, pulse width modulation (PWM) inverter has been developed. 2-level PWM inverter is widely accepted in industries for motor speed control, UPS, SMPS, grid interconnection and many other applications.

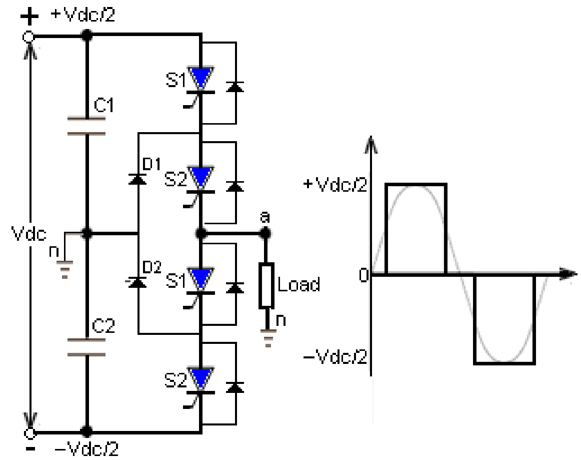

Figure 15. Representation of 3-level inverter.

5.2 3-level PWM Inverter: Though the 2-level PWM inverter is effective in removing most of the disadvantages of square wave inverter, still it had certain limitations due to poor wave shapes. This gave a thought of increase in the level of the inverter to achieve a near sinusoidal wave shapes. A three-level inverter as shown in Figure 15 is similar in design to that of a conventional two-level inverter but the numbers of semiconductor switching devices are double. Additional diodes called clamping diodes are also required to place in between the upper and lower switches and are connected to the neutral midpoint of the two capacitors. These capacitors build up the DC bus, each capacitor is charged with the voltage $\frac{Vdc}{2}$. This inverter creates the three voltages $\frac{Vdc}{2}$, 0, $-\frac{Vdc}{2}$ in each leg. In this way, by multiplying semiconductor devices in each leg higher levels can be added.

In Simulink model of short circuit alternator (see Figure 8) a 2-level IGBT based PWM inverter is put in place of CSI. The rectifier portion is kept untouched which is a thyristor based six pulse converter. After analysing results with a 2-level inverter it is replaced with a 3-level inverter for further experiments. From the measurement and display blocks, simulated waveforms of source voltage, current, motor voltage and current are plotted. Fast *Fourier transform (FFT)* frequency spectrums are taken on these waveforms to find out the THD levels. All are depicted in Figure 16 to Figure 19. Common mode voltage is also measured at the inverter output.

Table 2. Simulation results

Inverter	% THD source voltage	% THD source current	% THD motor voltage	% THD motor current	CMV V_{rms}
Existing	2.46	18.12	20.74	30.11	52.18
2-level	12.80	10.23	3.97	3.92	15.49
3-level	3.39	4.88	2.25	2.67	11.99

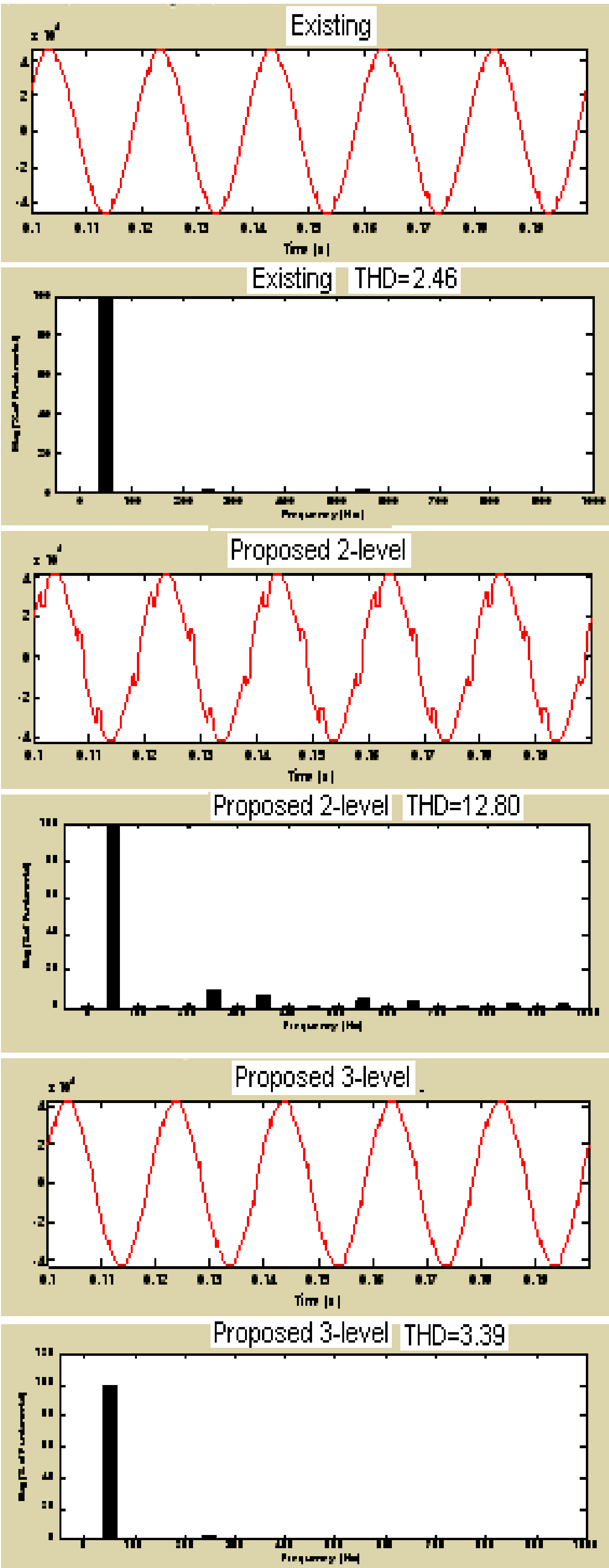

Figure 16. Source voltages & frequency spectrum.

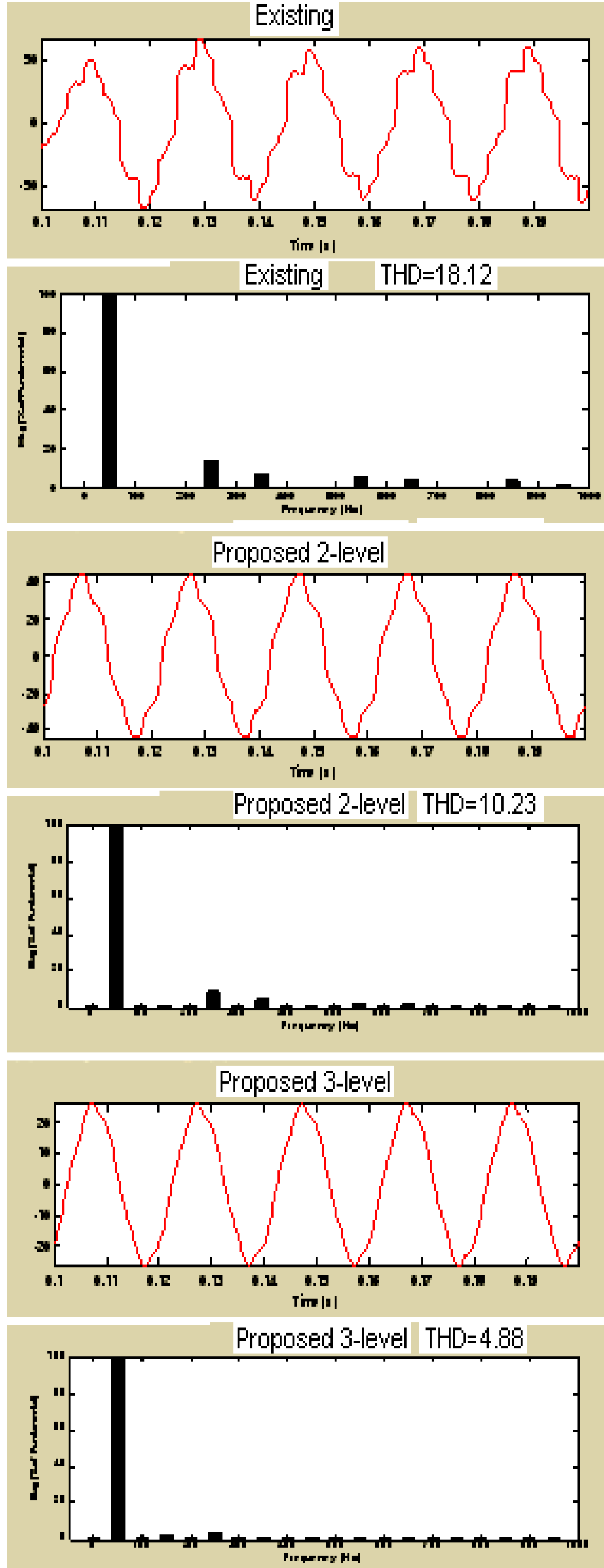

Figure 17. Source currents & frequency spectrum.

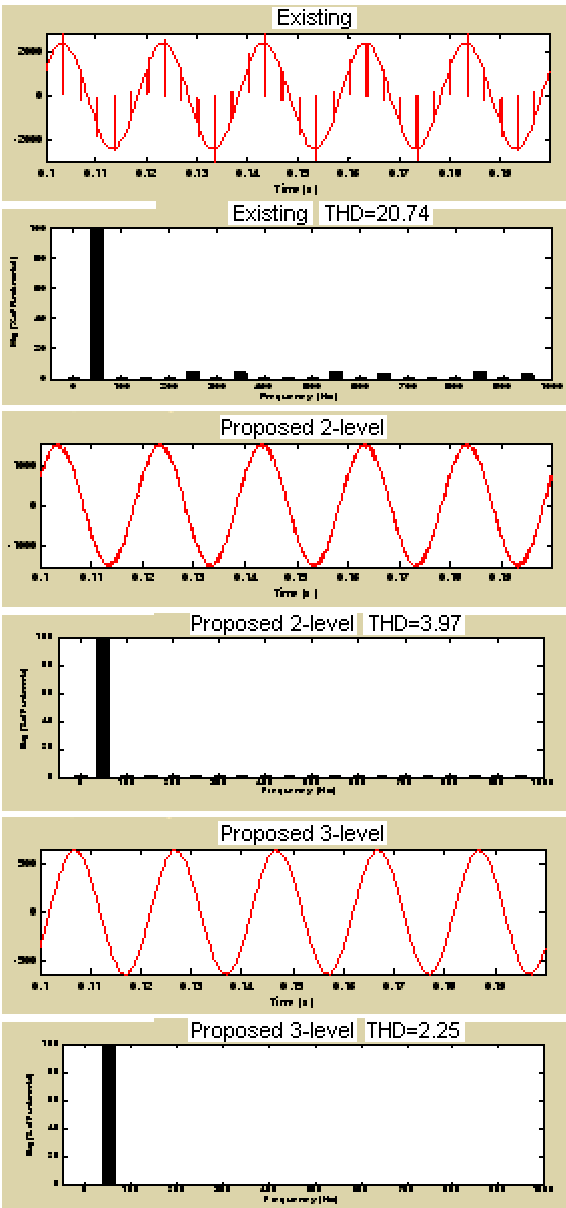

Figure 18. Motor terminal voltages & frequency spectrum.

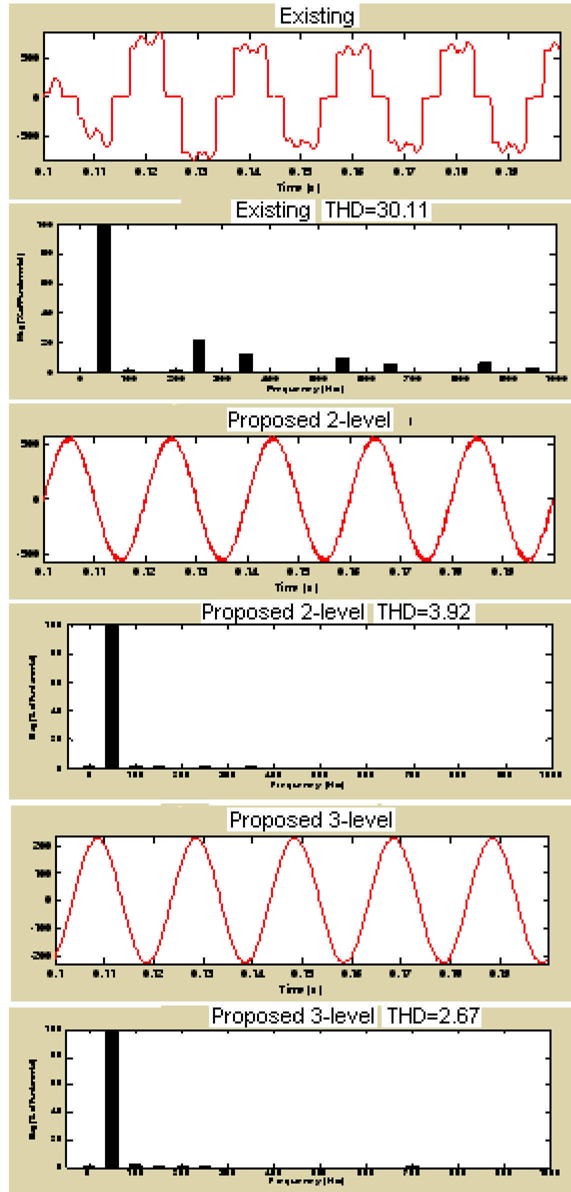

Figure 19. Motor currents & frequency spectrum.

6. Results and Discussions

After experimenting 2-level and 3-level inverter on the existing system the simulation results are tabulated in Table 2. It is observed from the Table 2 that for the existing system, harmonic distortion in the source voltage is only 2.46% whereas, current distortion is much more at 18.12%. THD in voltage and current at motor terminals is respectively 20.74% and 30.11%, i.e. extremely high. CMV is also a matter of concern with level of 52.18 Vrms. It is surmised that both 2-level and 3-level PWM inverters give considerable reduction in the level of harmonics and common mode voltage at motor terminals. In terms of source side THD, 3-level inverter shows definitely better results comparing to the 2-level inverter. The higher topology of MLI may also be experimented but there will not be much difference in results; rather circuit complexity and cost will increase. Shaft voltage directly depends on the level of harmonics in voltage and current at machine terminals. It also depends on the common mode voltage. As all of these parameters are reduced significantly on application of 3-level inverter hence shaft voltage is also going to be controlled by this method.

7. Conclusion

One of the objectives of this work is to find a solution to safeguard the shaft and bearing of a short circuit alternator from the ill effects of EDM caused by high CMV. Another objective is to limit harmonics generation. To study the system in detail its Simulink model is created through software with real data. Simulation studies show that present CSI based static drive is the prime cause for high level of CMV and THD. By virtue of MLI, supply wave shape can be kept near to sinusoidal which can further reduces the THD and CMV level. To prove this characteristic of MLI and to get control over EDM, replacement of present CSI in the system is done with a multilevel inverter in the model. Experimental results show that both 2-level and 3-level inverter gives considerable reduction in the level of harmonics and CMV at the machine terminals, but the later one is better in terms of overall achievements. Hence it is recommended that the present CSI may be replaced with a 3-level inverter to get rid of from the dangerous EDM at the machine shaft and bearing.

Though the study is done on a specific machine but its outcome can also be implemented to other large machines sourced with static power supplies.

References

1. Oliver Drubel, "Converter Dependent Design of Induction Machines in the Power range below 10MW", 1-4244-0743-5/07 2007 IEEE.
2. P. Langhorst, C. Hancock, "Simple Truth about Motor Drive Compatibility", MagneTek Publication, pp. 24-28, July 1996.
3. Hisanori Taguchi, Shinzo Tamai, Yasuhiko Hosokawa and Akinobu Ando, "APS Control Method for Gas Turbine Startup by SFC", International Power Electronics Conference, pp. 264-269, IEEE, 2010.
4. A. K. Datta, M. Dubey, S. Jain, 'Effect of Static Power Supply in Alternator Used for Short-Circuit Testing - Observation of Shaft Voltage', IEEE Transactions on Power Electronics, vol. 29, Issue: 11, pp. 6074–6080, Nov.2014. Datta Arun Kumar, Dubey Manisha, Jain Shailendra, "Effect of Static Power Supply in Alternator Used for Short-Circuit Testing - Observation of Shaft Voltage", IEEE Transactions on Power Electronics, vol. 29, Issue: 11, pp. 6074–6080, Nov.2014.
5. Arun Kumar Datta, N. R. Mondal, J. Santhosh, "Application of Static Frequency Converter on High Power Short Circuit Alternator – An Intelligent Step Towards Energy Efficiency Measure", International Conference on Recent Advances in Science, Engineering and Technology', organized by Science Globe, pp.1-6, 30th September 2018, Pune.
6. S. Bell, T. J. Cookson, S. A. Cope, R. A. Epperly, A. Fischer, D. W. Schlegel, and G. L. Skibinski, "Experience with variable-frequency drives and motor bearing reliability," IEEE Trans. Ind. Appl., vol. 37, no. 5, pp. 1438–1446, Sep./Oct. 2001
7. J. Adabi, F. Zare, F. Ledwich Gerard, and A. Ghosh, "Leakage current and common mode voltage issues in modern AC drive systems," in Proc. Australasian Universities Power Eng. Conf., Perth, Western Australia, 2007, pp. 641–646.
8. M. R. Baiju, K. K. Mohapatra, R. S. Kanchan, and K. Gopakumar, "A dual two-level inverter scheme with common mode voltage elimination for an induction motor drive," IEEE Trans. Power Electron., vol. 19, no. 3, pp. 794–805, May 2004.
9. R. S. Kanchan, P. N. Tekwani, and K. Gopakumar, "Three-level inverter scheme with common mode voltage elimination and DC link capacitor voltage balancing for an open-end winding induction motor drive," IEEE Trans. Power Electron., vol. 21, no. 6, pp. 1676–1683, Nov. 2006.
10. N. Zhu, D. Xu, B. Wu, N. R. Zargari, M. Kazerani, and F. Liu, "Common mode voltage reduction methods for current-source converters inmedium voltage drives," IEEE Trans. Power Electron., vol. 28, no. 2, pp. 995–1006, Feb. 2013.
11. H. Akagi and K. Isozaki, "A hybrid active filter for a three-phase 12-pulse diode rectifier used as the front end of a medium-voltage motor drive," IEEE Trans. Power Electron., vol. 27, no. 1, pp. 69–77, Jan. 2012.
12. Z. Zhao, Y. Zhong, H. Gao, L. Yuan, and T. Lu, "Hybrid selective harmonic elimination PWM for common-mode voltage reduction in three level neutral-point-clamped inverters for variable speed induction drives," IEEE Trans. Power Electron., vol. 27, no. 3, pp. 1152–1158, Mar. 2012.
13. K. K.-F. Yuen, H. S.-H. Chung, and V. S.-P. Cheung, "An active low loss motor terminal filter for overvoltage suppression and common-mode current reduction," IEEE Trans. Power Electron., vol. 27, no. 7, pp. 3158–3172, Jul. 2012.
14. Gordon R. Slemon, Sashi B. Dewan and James W. A. Wilson, "Synchronous Motor Drive with Current-Source Inverter", IEEE Transactions on Industrial Applications, Vol. IA-10, pp. 412-416, May/June 1974.
15. Arun Kumar Datta, N. R. Mondal, J. Santhosh, "Power Quality Study of 1500 MVA Motor-less Short Circuit Alternator", International Conference on Emerging Trends in Electronics, Electrical and Mechanical Engineering', organized by Technoarete International 27th, New Delhi. pp.50-54, January 2019.
16. F. Wang, "Motor shaft voltages and bearing currents and their reduction in multilevel medium-voltage PWM voltage-source-inverter drive appli- cations," IEEE Trans. Ind. Appl., vol. 36, no. 5, pp. 1336–1341, Sep./Oct. 2000.
17. H. Akagi and T. Doumoto, "An approach to eliminating high-frequency shaft voltage and ground leakage current from an inverter-driven motor," IEEE Trans. Ind. Appl., vol. 40, no. 4, pp. 1162–1169, Jul./Aug. 2004.
18. Nabae A., Takahashi I. and Akagi H., " A New Neutral-point Clamped PWM inverter", IEEE Transaction on Industrial Applications, Vol.IA-17, Sept./Oct. 1981, pp. 518-523.
19. Bhowmik S., Spee R., "A guide to the application oriented selection of AC/AC converter topologies", Power Electronics, IEEE Transactions on, vol.8, no.2, Apr 1990, pp. 156-163.

20. Raj C. Thanga, S. P. Srivastava and Pramod Agrawal, "Energy efficient control of three-phase induction motor- A review", international Journal of Computer and Electrical Engineering 1.1, 2009, pp. 1793-8198.
21. B. Robert and P. E. Fisher, "Introduction of static frequency converters on SEPTA's 25 Hz commuter rail system," in Proc. ASME/IEEE Railroad Conf., 1990, pp. 149–155.
22. Ho-Seon Ryu, Bong-Suck Kim, Joo-Hyun Lee and Ik-Hun Lim, "A Study of Synchronous Motor Drive using Static Frequency Converter" EPE-PEMC, pp.1496-1499, 2006, IEEE.
23. S.-H. Park, S.-H.Hwang, J.-M.Kim, H.-S. Ryu, and J.-H. Lee, "A starting- up control algorithm of large synchronous generation motor for gas turbosets," in Proc. IEEE Int. Symp. Ind. Electron., 2008, pp. 502–508.
24. Y.-Z. Zhang, "Study of process of starting pumped storage machines by static frequency converter with field current controlled," in Proc. IEEE Int. Conf. Signal Process. Syst., 2010, pp. V1-224–V1-227
25. Datta A. K., Manisha Dubey, N. R. Mondal, B. V. Raghavaiah, "Motor-less operation of Short Circuit generator – A CPRI Perspective", International Conference on Electrical Power and Energy Systems (ICEPES-2010), pp.439-445, 26-28 August 2010 MANIT, Bhopal.
26. T. Peterson and K. Frank, "Starting of large synchronous motor using static frequency converter," in Proc. IEEE Summer Meet. Int. Symp. High Power Testing, Portland, Ore., Jul. 18–23, 1971, pp. 172–179.
27. A. K. Datta, M. A. Ansari, N. R.Mondal, and B. V. Raghavaiah, "A novel use of power electronics: prime mover-less alternator with static drive & excitation system," Int. J. Electron. Commun. Technol., vol. 3, no. 1, pp. 472–475, Jan./Mar. 2012.
28. M. H. Rasheed, "Power Electronics Handbook", 2001, Academic Press.
29. Arun Kumar Datta, "Energy management in operation of motorless short circuit alternator", Annual Technical Volume of Electrical Engineering Division Board of Institution of Engineers (India), pp. 65-72, 2020.
30. Ojha Amit, "Investigations on back-to-back connected multilevel converter fed induction motor drive", Ph.D. Dissertation, MANIT, Bhopal (India), 2013.
31. The MathWorks^{TM}, Inc., USA, Release 2008a (R2008a).
32. Arun Kumar Datta, "Modelling and simulation analysis of static drive for large synchronous machine", CIGRE Science & Engineering, pp. 12-21 February 2016, France.
33. Arun Kumar Datta, Manisha Dubey, Shailendra Jain, M. A. Ansari, N. R. Mondal, B. V. Raghavaiah, 'Simulation of Static Frequency Converter for Synchronous Machine Operation and Investigation of Shaft Voltage', International Journal of Electrical, Electronic Science and Engineering, World Academy of Science, Engineering and Technology (WASET) pp. 95-100, Vol.8 No.3, 2014.
34. Datta Arun Kumar, Dubey Manisha, Jain Shailendra, "Investigation of bearing currents in dual mode operation of synchronous machine with static excitation system," pp. 45-53, Electrical and Electronics Engineering: An International Journal (ELELIJ) Vol 2, No 4, November 2013.
35. Datta Arun Kumar, Dubey Manisha, Jain Shailendra, "Modelling and Simulation of Static Excitation System in Synchronous Machine Operation and Investigation of Shaft Voltage", Advances in Electrical Engineering, Hindawi Publishing Corporation, Published 3 July 2014 Volume 2014.
36. Andrzej M. Trzynadlowski, EMI Effects of Power Converters, Chapter 40, Power Electronics Handbook, edited by Muhammad H. Rashid, pp.1103-1119, 2007, Elsevier Inc.
37. Arun Kumar Datta, "Technology Upgradation with Multi Level Inverter – A Scheme for Life Enhancement of Short Circuit Alternator", 30th Indian Engineering Congress, organized by The Institution of Engineers (India), 17th – 20th December 2015, Guwahati.
38. Arun Kumar Datta, N. R. Mondal, J. Santhosh, "A Scheme for Harmonic Reduction with Multilevel Inverter in Large Synchronous Machine Powered by Static Drive", Proceedings of IRF International Conference, pp.22-282, 5th February, 2018, Kanyakumari.

Biographical notes

Arun Kumar Datta has received his Ph.D. from MANIT, Bhopal in Electrical Engineering in 2015. He did his M.Tech. from MACT Bhopal in 1992 and B.E. from Government Engineering College, Bilaspur in 1990. He is working in Central Power Research Institute (CPRI), Bhopal since 1993 and presently he is the HoD of Operation & Maintenance Division of two 1500MVA short circuit generator plant and 33kV substation. He is also looking after the Quality Assurance activities of CPRI. He had undergone training at the works of M/s. Alsthom, France. He is a Certified Energy Auditor by BEE. He is an IEEE member and also a Fellow of Institution of Engineers (India). NABL has certified him as lead Assessor as per ISO/IEC 17025. He has attended many International & National Conferences and presented many papers at different forums also organised many conferences, seminars and workshops.