Review on Rotor Inter Turn Fault Detection in Hydro Generator

Atul Chadda[1] and PiushVerma[2]

[1, 2] *National Institute of Technical Teachers Training & Research, Chandigarh, 160019, India.*

Abstract

Hydro generators are considered as an essential component in power generation system as it transforms turbine's mechanical energy into electrical power. The main focus of this paper is based on inter- turn fault in salient pole rotor that mostly occurs in standard synchronous generators. Most of the synchronous generators come across with winding short circuit failures. It is mandatory to detect fault at an early stage and take appropriate diagnosis methods to overcome it. From the literature survey conducted, it is observed that there are number of techniques proposed by various researchers to detect the faults in hydro generators. These techniques were able to assess fault position, detect fault at an early stage, and to cope up with rotor intern-turn. Furthermore, less research has been done by researchers on various dependences factors of fault detection and in future there is a great scope of development of various decision modeling approaches for online fault detection.

Key words

Inter turn fault, Power systems, Hydro generators, Fuzzy Inference Systems (FIS), Intelligent systems etc.

1. INTRODUCTION

The most pressing issues in today's world are that everyone should have access to a reliable and affordable source of electricity. High greenhouse gas emissions have resulted in dramatic shifts in the environment. As a result, it is necessary to shift towards the RESs. Wind, Solar, and hydropower are examples of such power resources [1-2].The hydro generator turns the turbine's mechanical energy into electric power. The mechanical torque of turbine shaft is applied to the rotor which is a spinning assembly. The voltage is inducted in the stationary element, the stator, by magnetizing or "exciting" the rotor. The output voltage is set and stabilized by the exciter regulator. With the exception of an increased speed, the turbine selection determines the generator's speed.

A loss in speed produces generator physical size and cost for a definite value of power [3]. Furthermore, the hydro generators are classified into four categories as shown in figure1.1.

International Conference on Emerging Technologies: AI, IoT, and CPS for Science & Technology Applications, September 06–07, 2021, NITTTR Chandigarh, India
EMAIL: atulchadda@gmail.com (A. 1); piush@nitttrchd.ac.in (A. 2)
ORCID: 0000-0001-9192-7028 (A. 1); 0000-0002-4100-7159 (A. 2)

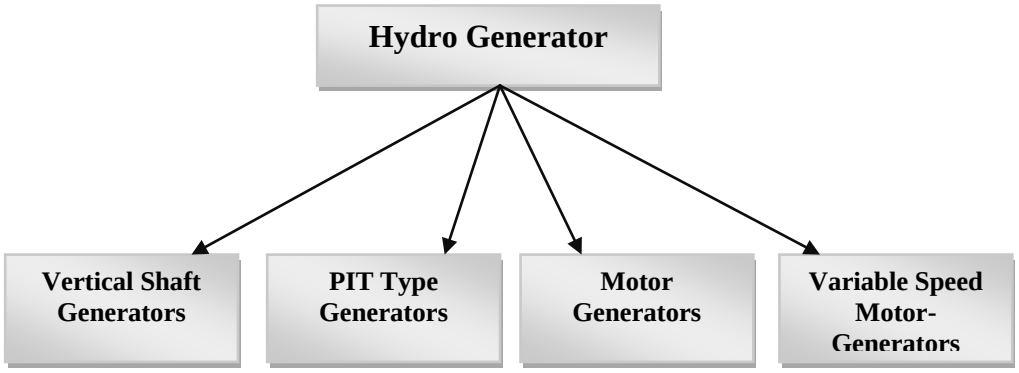

Figure 1.1 Types of generators

Vertical Shaft Generators: The turbines with Vertical shaft especially in hydro are connected to vertical shaft generator with outputs ranging up to 840 MVA. Vertical generators for Pelton, Kaplan, and Francis turbines have been used in the past for a wide variety of outcomes and speeds.
PIT type Generators: PIT generators have been used in low-head implementations and that is the reason it is connected to the horizontal turbine shaft by use of step-up gear. PIT implementations are a cost-effective alternative for hydropower stations with low head and lower ratings (typically up to 17 MVA). PIT generators are known for their solid design and ability to withstand the high runaway speeds needed by hydropower plants.
Motor Generators: To operate pump turbines and produce electricity, pumped storage plants utilize motor generators. With novel adaptive speed and one or two rotation directions, motorized generators for the implementation of pumped storage. It could exceed up to 360 Million Volt-Amps.
Variable Speed Motor-Generators: To maintain synchrony with the grid frequency, the turbine and generator's rotational speeds should be constant in traditional plants. The grid's capacity to provide ancillary services is constrained under these conditions. Furthermore, at a constant speed, the pumped-storage plants prevent the pumping power from being adjusted, therefore restricting the most efficient usage surplus electricity [4].
Any enterprise or process's overall economy is highly dependent on fault detection. Vibration-signal-, knowledge-, and Model-based methods are currently three types of approaches that are based on HGU's fault diagnosis [5]. Researchers have studied a wide variety of system defects, such as uneven stator plus rotor, eccentricity in addition to bearing faults with split rotor bars. Generator breakdown can cause significant economic losses for the HGU. Fault identification, study and control are therefore very critical activities to be considered in order to prevent significant economic losses. This will reduce unexpected faults, downtime repairs and operating costs. It could also be avoided to operate electrical equipment in dangerous conditions.

1.1. Inter-Turn Short Circuit Fault

Rotor inter-turn short circuit fault is a type of synchronous generator failure. Synchronous generators have complicated structure, high voltage and high workload characteristics. Moreover, the generator rotor is under rotary vibration for a long period and can lead to failure. The rotor windings failure of the inter-turn short circuit is more prevalent [6]. Most synchronous generators occurred with an excitement winding short circuit failure or were defective [7, 8]. The rotor winding short-circuit result into increased excitation and intensifying rotor vibration in the broad synchronous generator [9, 10]. The fault features of inter-turn winding are too small to be effectively established in the initial stage. If a short circuit fault is not resolved, the rotor winding

inter-circuit may result in a major mishap and pose a considerable risk to the safe operation of the generator and the power system. The safe, consistent operation of the synchronous generator is critical to ensuring that the power supply of the electrical system is safe, and the synchronous generator rotor winding inter-turn failure in the early stage needs to be established.

2. LITERATURE

As discussed in the previous section that the rotorinter turn short circuit may result for major accident and many other impacts, therefore it is mandatory to early detection of such faults and takes appropriate precautions to overcome it. There are number of techniques those are proposed by researcher for detection as well as for diagnosis purpose. This section presentsa literature survey of various short circuits related fault detection and prevention approach. Following this review, a tabular comparison for these techniques is also mentioned. Finally, a conclusion and future scope of research in given.Yong-gang Li, et al. [11], presented the reverse calculation approach for the no-load curve and used just electrical parameters like active, reactive, voltage, and current. A. Ur Rehman et al., [12], proposes a method for detection of inter-turn short circuit faults in rotor winding relied on fundamental electrical characteristics. C. Wei, et al. [13], proposed a failure diagnostics technique to deal mostly with rotor windings which were utilized for online fault control, inter-turn short circuit fault those are found in synchronous condenser. W. Shuting and T. Haixia, [14],the parallel linked branches of the stator, which circulate current features, due to the inter-turn failure of the rotor winding were examined. Also, a system is designed for fault diagnoses using virtual instruments. H. Sabir, et al. [15], developed a combined technique based on CSA (Current Signature Analysis) and TSA (Time Synchronous Averaging) to boost the wind turbine control system and the DFIG down time S. E. Zouzou, et al. [16], proposed to employ the PRI (Partial Relative Indexes) as fault indicators to enhance the fault detection process.L. Yong-gang et al. [17], evaluated the variations in electromagnetic characteristics, electrical parameters as well as the defect specifications which maximize the field current and reduce reactive power after failure to propose a new online methodology for analyzing the rotor inter-turn failure of the brushless excitation synchronous generator. F. Sun, et al. [18], an RSO approach was developed to assess the fault position of the inter-turn short circuit by examining the signal propagation time, winding symmetry and fault function database.T. D. Razafimahefaet al. [19], designed a turnaround short circuit in the induction machine's stator and rotor windings as well as the identification of a defect in startup.S. S. S. R. Sarathbabu Duvvuri, et al. [20], developed an induction motor models with reference framework theory. The diagnostic significance for the short-speed rotor turn-to - turn faults of these SRIM models was studied.

Table 1
Comparison table for different work done

S. No.	Author Name	Year	Work Done
1	Yong-gang Li et al. [11]	2018	Presented the reverse calculation approach for the no-load curve.
2	A.UrRehman et al. [12]	2016	Proposed a framework named as FEM also termed as Finite Element Method, to verifying the functioning of the generators.
3	Wei et al. [13]	2019	Proposed a failure diagnostics technique to deal mostly with rotor windings which were utilized for online fault control, inter-turn short circuit fault those are found in synchronous condenser.

4	W. Shuting and T. Haixia [14]	2007	Examined the parallel linked branches of the stator and by using virtual instruments the authors designed a system for fault diagnoses.
5	H. Sabir et al. [15]	2018	Developed a strategy to boost the wind turbine control system and the DFIG downtime.
6	S. E. Zouzou et al. [16]	2010	Proposed an enhanced the fault detection process, the authors in this paper employed the PRI (Partial Relative Indexes) as new fault indicators.
7	L. Yong-gang et al. [17]	2016	Proposed a new online methodology for analyzing the rotor inter-turn failure in the brushless excitation synchronous generators.
8	F. Sun et al. [18]	2019	Proposed a an RSO approach to assess the fault positioning of the inter-turn short circuit by examining time of the signal propagation , winding symmetry and fault function database
9	T. D. Razafimahefa et al. [19]	2015	Proposednew state-space induction motor models with reference framework theory.
10	S. S. R. SarathbabuDuvvuri et al. [20]	2018	This article proposed a model to handle the inter turn short circuit fault particularly for rotor windings. It has the feature of online monitoring also.

3. CONCLUSION

This article provides an overview to hydro power generators and detail description of the inter turn short circuit fault. From the literature survey, it is observed that hydro generator rotor fault detection techniques are inaccessible or complicated. For detection as well as for diagnosis purpose, a large number of techniques were proposed by researchers. In addition to this, various methods were proposed by researchers to deal with rotor inter-turn fault short circuit. After analyzing various papers based on intern-turn fault short circuit we find that there is a scope of improvements in these methods to detect fault at an early stage. Furthermore, various decision modeling approaches could be made using dependences factors of online fault detection.

4. ACKNOWELGEMENT

The authors are thankful to NITTTR Chandigarh and NHPC Limited for providing necessary support and directions for this work.

5. REFERENCE

[1] Sidi Mohammed Kaddour and Mohamed Lehsaini, “Electricity Consumption Data Analysis Using Various Outlier Detection Methods, International Journal of Software Science and Computational Intelligence (IJSSCI), vol. 13(3), 2021

[2] O. A. Aqel, M., Issa, A., Qasem, E., & El-Khatib, W, “Hydroelectric Generation from Water Pipelines of Buildings”, 2018 International Conference on Promising Electronic Technologies (ICPET), pp. 63-68, 2018.

[3] Hatata, A. Y., El-Saadawi, M. M., &Saad, S., “A feasibility study of small hydro power for selected locations in Egypt”, Energy Strategy Reviews, pp. 300–313, 2019.

[4] Emiliano Corà et al., “Hydropower Technologies”, Hydropower Europe, pp. 1-73, 2019.

[5] G. Liao, W. Gao, G. Yang and M. Guo, "Hydroelectric Generating Unit Fault Diagnosis Using 1-D Convolutional Neural Network and Gated Recurrent Unit in Small Hydro," in IEEE Sensors Journal, vol. 19, pp. 9352-9363, 15 Oct.15, 2019.

[6] Luo Wang, Yonggang Li and Junqing Li, “Diagnosis of Inter-Turn Short Circuit of Synchronous Generator Rotor Winding Based on Volterra Kernel Identification”, Energies, pp. 1-15, 2018.

[7] Zhang, G.; Wu, J.; Hao, L. Analysis on the amplitude and frequency characteristics of the rotor unbalanced magnetic pull of a multi-pole synchronous generator with inter-turn short circuit of field windings. Energies, pp. 1-20, 2018.

[8] Wu, Y.; Li, Y, “Diagnosis of rotor winding interturn short-circuit in turbine generators using virtual power”, IEEE Trans. Energy Convers, pp.183–188, 2015.

[9] Hao, L.; Wu, J.; Zhou, Y, “Theoretical analysis and calculation model of the electromagnetic torque of nonsalient-pole synchronous machines with interturn short circuit in field windings”, IEEE Trans. Energy Convers, 110–121, 2015.

[10] Zhang, G.; Wu, J.; Hao, L, “Fast calculation model and theoretical analysis of rotor unbalanced magnetic pull for inter-turn short circuit of field windings of non-salient pole generators”, Energies, 1-19, 2017.

[11] Yong-gang Li, Luo Wang, Ming-han Ma, “Diagnosis of Rotor Winding Inter-Turn Short-Circuit of Hydro-Generator Based on No-load Curve Reverse Calculation”, IEEJ TRANSACTIONS ON ELECTRICAL AND ELECTRONIC ENGINEERING, IEEJ Trans, 2018.

[12] Ur Rehman, Y. Chen, L. Wang, Y. Zhao, Y. Cheng and T. Tanaka, "Simulation using MATLAB/Simulink on rotor winding inter-turn short circuit fault in DFIG," 2016 IEEE International Conference on Dielectrics (ICD), pp. 506-509, 2016.

[13] Wei, L. Sun, W. Wang, Y. Lin, W. Tian and M. Cheng, "A Fault Diagnosis Strategy for Rotor Windings Inter-Turn Short Circuit of Synchronous Condenser," 2019 22nd International Conference on Electrical Machines and Systems (ICEMS), pp. 1-5, 2019.

[14] W. Shuting and T. Haixia, "Design of the Fault Diagnosis System of Generator Rotor Winding Inter-Turn Short Circuit Based on Virtual Instrument," 2007 8th International Conference on Electronic Measurement and Instruments, pp. 3-576-3-580, 2007.

[15] H. Sabir, M. Ouassaid and N. Ngote, "Diagnosis of Rotor Winding Inter-Turn Short Circuit Fault in Wind Turbine Based on DFIG Using the TSA-CSA Method," 2018 International Symposium on Advanced Electrical and Communication Technologies (ISAECT), pp. 1-5, 2018.

[16] S. E. Zouzou, M. Sahraoui, A. Ghoggal and S. Guedidi, "Detection of inter-turn short-circuit and broken rotor bars in induction motors using the Partial Relative Indexes: Application on the MCSA," The XIX International Conference on Electrical Machines - ICEM 2010, pp. 1-6, 2010.

[17] L. Yong-gang, M. Ming-han, W. Yu-cai and B. Guo-bang, "The new criterion of brushless excitation generator rotor winding inter-turn short circuit fault diagnosis based on reactive relative deviation," 2016 19th International Conference on Electrical Machines and Systems (ICEMS), pp. 1-4, 2016.

[18] F. Sun, J. Wang, M. Li, A. Wang, Z. Cao and S. Sun, "Research on Fault Location Method for Inter-Turn Short Circuit of Turbo-generator Rotor," 2019 4th International Conference on Power and Renewable Energy (ICPRE), pp. 326-330, 2019.

[19] T. D. Razafimahefa, N. Heraud, E. J. R. Sambatra and O. Wailly, "Comparative study of inter-turn short circuit fault in stator and rotor windings on a small and Medium Power Wound Rotor Induction Machine," 2015 23rd Mediterranean Conference on Control and Automation (MED), pp. 184-189, 2015.

[20] S. S. S. R. SarathbabuDuvvuri, "Rotor Inter-turn Short-circuit Fault Diagnostics Relevant Modeling of Slip-Ring Induction Motor," 2018 IEEE 8th Power India International Conference (PIICON), Kurukshetra, India, 2018, pp. 1-6, 2018.

[21] Hussain, Aziza Ibrahim and Ahmed Zakaria Sayed. "Optimal User Association of LTE/Wi-Fi/Wi-Gig Bands in 5G Cellular Networks." *IJSWIS* vol.17, no.2 2021: pp.22-40.

[22] Tewari, Aakanksha and Brij B. Gupta. "Secure Timestamp-Based Mutual Authentication Protocol for IoT Devices Using RFID Tags." *IJSWIS* vol.16, no.3 2020: pp.20-34.

[23] BesmirSejdiu&Florije Ismaili &LuleAhmedi, 2020. "Integration of Semantics into Sensor Data for the IoT: A Systematic Literature Review," International Journal on Semantic Web and Information Systems (IJSWIS), IGI Global, vol. 16(4), pages 1-25, October.