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Analysis of Automatic Voltage Regulator (AVR) Performance Based on Commissioning Load Acceptance and Load Rejection Data at 28 MW Capacity Steam Power Plant

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ABSTRACT

As the load changes, the voltage produced by the generator will always change due to the fluctuating load. The output voltage must be kept constant within the desired value to ensure the supply of generator output power in order to meet the needs of the load, then a device called AVR (Automatic Voltage Regulator) is needed. AVR aims to regulate the amount of excitation current supplied to the generator and the amount of excitation current is directly proportional to the amount of voltage produced by the generator. This study aims to analyze the performance of AVR in maintaining the stability of voltage and generator output power at 28 MW Steam Power Plant. Monitoring the performance of the AVR installed on the generator is carried out during commissioning and testing. The test results and analysis after the generator is installed AVR can be seen that the output voltage is in stability with a variation value between 5% of the nominal output voltage value of 11 KV, which shows the success of installing AVR to stabilize the output voltage remains constant and can meet the needs of the load.

Keywords: Generator, Automatic Voltage Regulator, excitation current, output power, output voltage.

Introduction

Automatic Voltage Regulator (AVR) is an important component in power generation and transmission systems. Its main function is to maintain a constant output voltage amidst load changes and other external factors [1]. The AVR achieves this by regulating the generator output voltage through the adjustment of the excitation current, based on the desired voltage level. Two commonly used controllers in AVR systems are the PID (Proportional-Integral-Derivative) controller and the CRONE (Commande Robuste d'Ordre Non Entier) controller [2], [3]. PID controllers are suitable for handling complex control tasks, while CRONE controllers offer better tuning and flexibility [4].

The design and implementation of AVR systems involves the use of various components such as microcontrollers, sensors, MOSFETs, and buck converters [5]. Proper selection of components and tuning of controller parameters are essential to achieve optimal performance [2]. The performance evaluation of AVR systems is based on criteria such as transient analysis, overshot, rise time, settling time, and steady-state error, which

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helps in comparing different control strategies and optimizing system effectiveness [2].

According to Başlık et al. [6], AVR has several important functions in power systems. One of its main tasks is to ensure a stable generator terminal voltage, which is crucial for maintaining the quality and reliability of electric power. The AVR achieves this by keeping the terminal voltage within a specified range, thus preventing damage to the equipment and maintaining the high quality of the generated power. In addition, the AVR regulates the excitation voltage of the generator, which directly affects the terminal voltage [7], [8]. These adjustments ensure that the generator operates within the specified specifications and produces stable and controllable power [9], [10]. In addition, AVRs also contribute to power system stability by monitoring terminal voltages and automatically adjusting generator excitation to prevent voltage collapse that could lead to outages [8], [11]. Finally, AVRs improve power quality by avoiding voltage fluctuations that can disrupt electrical equipment [7], [8]. Overall, AVRs play an important role in maintaining voltage stability, regulating excitation voltage, improving system stability, and maintaining power quality [12], [13].

AVR performance analysis is performed to understand how the system regulates and monitors voltage in the distribution network [6]. The objective of this analysis is to achieve voltage regulation, improve generator performance, reduce disturbances, and optimize resource utilization. The analysis involves assessing various parameters such as voltage, generator performance, system stability, and risk of failure. The AVR ensures that the voltage remains within acceptable limits, guaranteeing the reliability and quality of the power supply [6]. By effectively regulating the mains voltage, AVRs optimize generator performance, improve system stability, and minimize the possibility of failure. In addition, AVRs reduce disturbances to the electrical system, ensuring a consistent and reliable supply of electricity. Finally, AVRs contribute to resource optimization by accurately regulating the mains voltage, improving efficiency and reliability in the electrical system [6]. This study aims to analyze the performance of AVRs in maintaining the stability of voltage and generator output power at a 28 MW Steam Power Plant. Monitoring the performance of the AVR installed on the generator is carried out during commissioning and testing.

Methods

This study uses the correlation analysis method to assess the performance of the Automatic Voltage Regulator (AVR) during the commissioning phase of the generator. The commissioning process is carried out to assess the performance of the AVR by observing the relationship between different operating conditions [14], as in this study using no-load testing and load testing. Using this method can make it possible to identify how the AVR responds to various load scenarios. The testing phase can be seen in **Figure 1**.

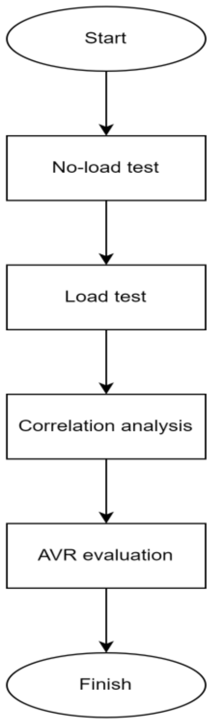

Figure 1. Testing phase

The first phase executed no-load testing. During no-load testing, the AVR is monitored to ensure that it can maintain a stable voltage output without external loads affecting the performance of the generator. This phase provides baseline data, helping to isolate the AVR's behavior from the complexities of load variations.

In the second phase, load testing was conducted. In this phase, the generator is subjected to varying loads to observe how the AVR adapts to changing demands. Correlation analysis in this phase is critical to understanding the system's ability to stabilize voltage in real-time as load conditions fluctuate. Comparison between no-load and load test results allows researchers to identify patterns, correlations, and potential performance issues. This data-driven approach to test results is useful for ensuring that any deviations in voltage regulation can be quickly identified and resolved before the system is fully operational.

After commissioning, the generator is exposed to different load levels to evaluate the long-term performance of the AVR under practical operating conditions. The correlation between the AVR output and the applied load is monitored to ensure that the regulator maintains the voltage within acceptable limits. These tests are critical to ensure that the AVR will function properly during real-world applications, where load conditions change frequently. The final analysis will involve comparing the AVR's performance across different load scenarios, highlighting any adjustments or tuning required to optimize the system.

Results and Discussion

Some electrical system parameters are mandatory for commissioning to ensure the system is running properly [14], [15]. Commissioning is the process of testing the equipment to be applied. AVR commissioning is done to test whether the AVR to be implemented functions according to existing needs. The following is an explanation of the AVR parameters that will be commissioned:

- Soft Start is a technique to reduce inrush current and mechanical torque when starting an engine or generator. This process involves a gradual increase in voltage or frequency from zero to nominal values to avoid current and voltage spikes that can damage equipment and reduce component life. The results of soft start can be seen in **Figure 2**. The figure explains that the output voltage from 0 KV to 11.21 KV, then lowered stabilized down to 11 KV.

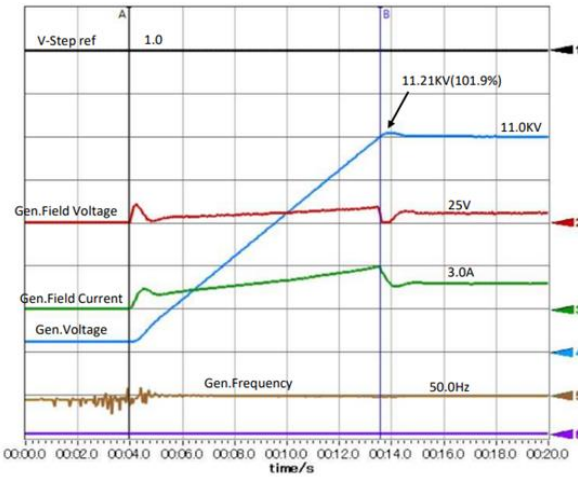

Figure 2. AVR Soft start

- Step Response Test is a test method for evaluating the dynamic response of an AVR or other control system. This test involves providing a sudden change (step change) to the voltage reference input and observing how the output voltage responds. The results of the Step Response Test can be seen in Figure 3. In the figure, it can be seen that the output voltage which is initially 11 KV, then suddenly lowered and raised again can stabilize at 11 KV.

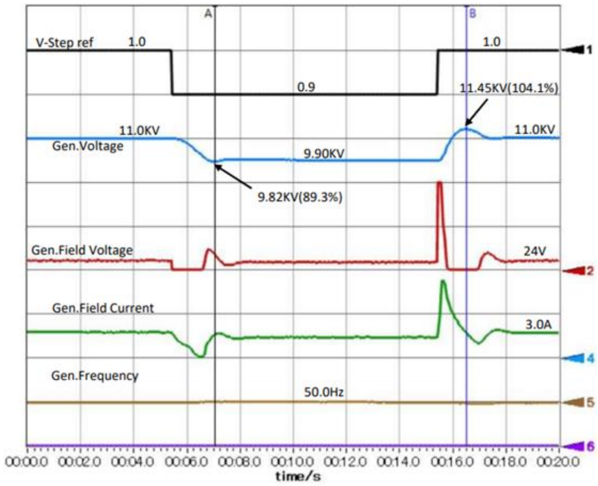

Figure 3. AVR Step response

- Adjustable Voltage Range is the AVR's ability to adjust the generator output voltage within a desired range. This allows the operator to set the output

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voltage according to the specific needs of the application or system.

- Adjustable Frequency Range is the ability to adjust the generator output frequency within a desired range. Although AVRs primarily control voltage, frequency is usually regulated by engine governors or speed control systems.
- Change Over Operation is the process of switching from one source of electrical power to another to ensure an uninterrupted supply of electricity. It is often used in systems that have a backup power source or backup generator. The results of this process can be seen in **Figure 4**. At the 7th second a change point occurs which causes a voltage overshoot to 11.09 KV. This is still within the limit and the voltage stabilizes again at 11 KV.

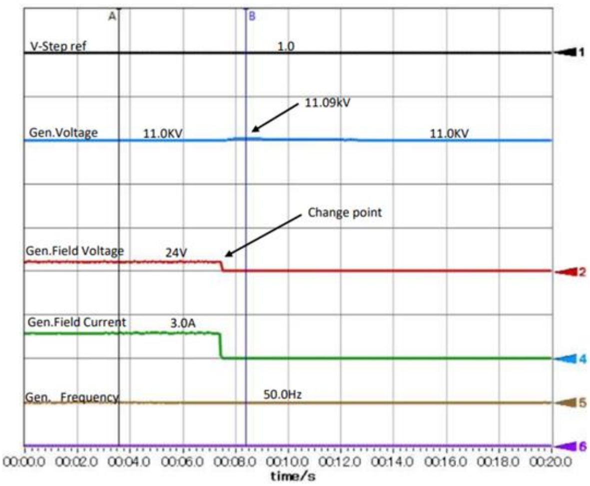

Figure 4. AVR Change over operation

- AVR control is confirmation that AVR operation should work correctly under load conditions.
- The load rejection test is confirmation that the AVR operation should work stably during the load rejection test. These results can be seen in **Figure 5**. In this process where the generator releases a load of 4.8 MW. In this process it can be seen that the generator experienced an overshoot of 0.48% (well within the set limit) and stabilized again.

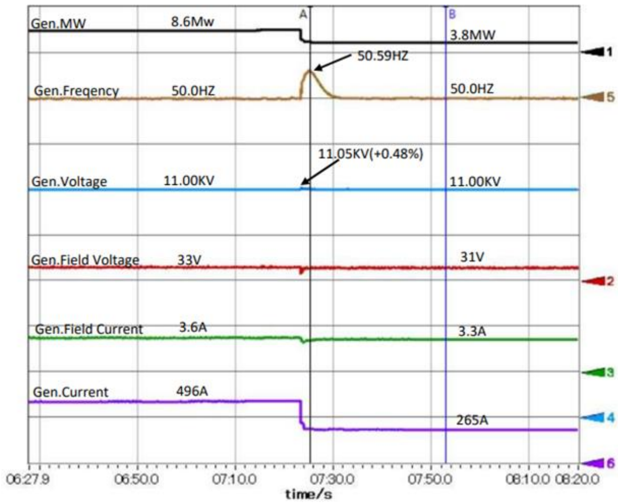

Figure 5. 4.8 MW Load rejection test

Based on the results found during the commissioning process, it can be concluded that the AVR applied to the generator functions properly and runs as needed.

After commissioning the AVR will be implemented with several loads to be tested by giving and removing several loads (load ON/OFF). This is to test the AVR response to load spikes and drops. The generator experiments will be given loads of 2 MW, 3 MW, 4 MW, and 4.8 MW. **Figure 6-9** is the result of the load ON/OFF test.

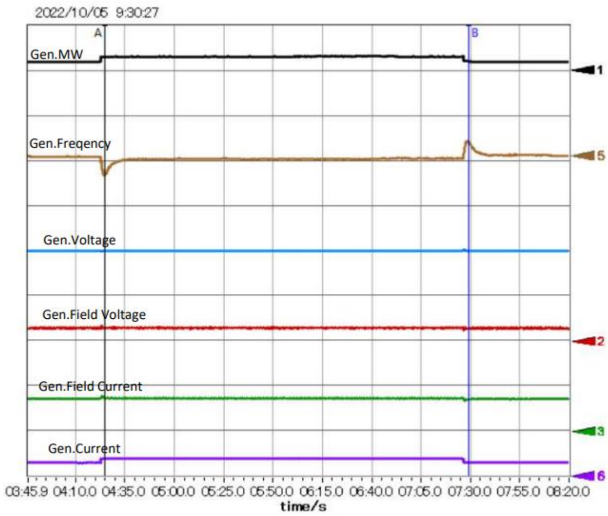

Figure 6. 2 MW Load ON/OFF test

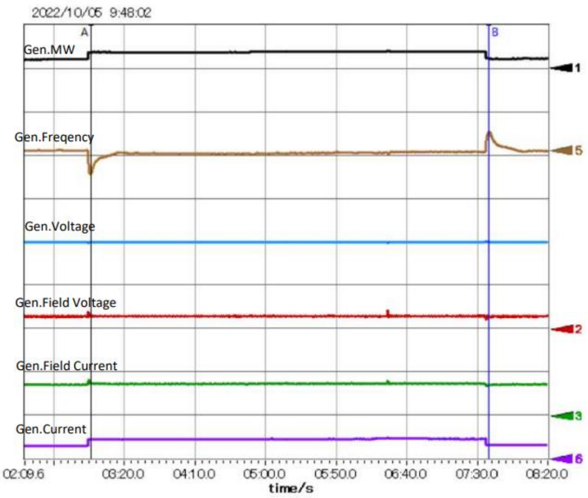

Figure 7. 3 MW Load ON/OFF test

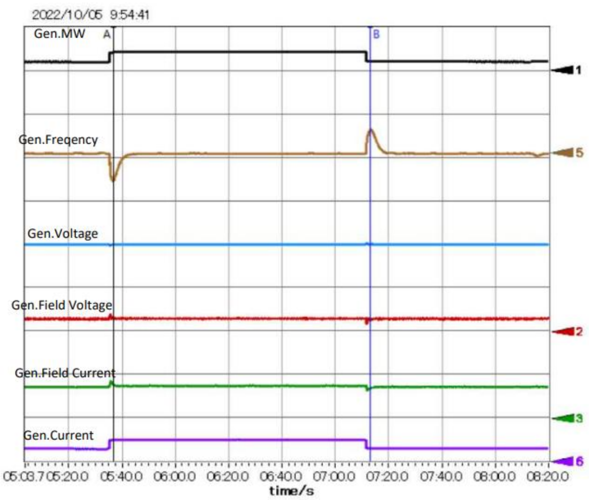

Figure 8. 4 MW Load ON/OFF test

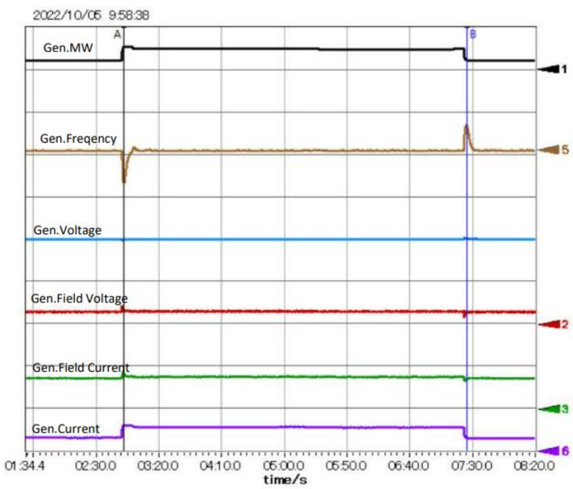

Figure 9. 4.8 MW Load ON/OFF test

In **Figure 6-9**, it can be seen that when there is an additional load (load ON), the generator still stabilizes the voltage at 11 KV, as well as when there is a load reduction (load OFF). The results of monitoring and analysis after the generator is installed AVR can be seen that the output voltage is in stability with a variation value between 5% of the nominal output voltage value of 11 KV [16]. Based on these results, it can be concluded that the AVR can stabilize the output voltage of the generator.

Conclusions

Load changes that also fluctuate will make the voltage produced by the generator will always change. The output voltage must be kept constant within the desired value to ensure the supply of generator output power to meet the load requirements. The AVR aims to regulate the amount of excitation current supplied to the generator and the amount of excitation current is directly proportional to the amount of voltage produced by the generator. Monitoring the performance of the AVR installed on the generator is carried out during commissioning and testing. The results of monitoring and analysis after the generator is installed AVR can be seen that the output voltage is in stability with a variation value between 5% of the nominal output voltage value of 11 KV, which shows the success of installing AVR to stabilize the output voltage remains constant and can meet the needs of the load.

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Author Contributions
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Conflicts of Interest
Authors state no conflict of interest.

References

[1] A. Pangkung, M. Marhatang, C. N. Irlan, and U. Fasiha, "Analisis Pengaruh Penggunaan AVR (Automatic Voltage

ISSN : 2085 – 1669
e-ISSN : 2460 – 0288

Regulator) Terhadap Sistem Eksitasi Generator Pada BTG 1 (Boiler Turbin Generator) PT. Semen Tonasa," *Jurnal Sinergi Jurusan Teknik Mesin*, vol. 16, no. 1, p. 42, May 2019, doi: https://doi.org/10.31963/sinergi.v16i1.1201.

[2] S. Alghamdi, A. B. Wazir, H. H. H. Awaji, A. A. Alhussainy, H. F. Sindi, and M. Rawa, "Tuning PID Controller Parameters of Automatic Voltage Regulator (AVR) Using Particle Swarm Optimization : A Comparative Study," *2023 IEEE PES Conference on Innovative Smart Grid Technologies - Middle East (ISGT Middle East)*, pp. 1–6, Mar. 2023, doi: https://doi.org/10.1109/ISGTMiddleEast56437.2023.10078497.

[3] Busra Ozgenc, Mustafa Sinasi Ayas, and Ismail Hakki Altas, "Performance improvement of an AVR system by symbiotic organism search algorithm-based PID-F controller," *Neural computing & applications*, vol. 34, no. 10, pp. 7899–7908, Jan. 2022, doi: https://doi.org/10.1007/s00521-022-06892-4.

[4] P. Shah, R. Sekhar, and M. Shah, "Design and Implementation of CRONE Controller for Automatic Voltage Regulator (AVR) System," *2022 IEEE Bombay Section Signature Conference (IBSSC)*, Dec. 2022, doi: https://doi.org/10.1109/ibssc56953.2022.10037437.

[5] R. Putra, M. T. Ir. Hery Purnomo, and M. T. Ir. Soeprapto, "Rancang Bangun Sistem Pengaturan Eksitasi Pada Generator Sinkron 3 Fasa Menggunakan Automatic Voltage Regulator (AVR).," *repository.ub.ac.id*, Nov. 03, 2016. https://repository.ub.ac.id/id/eprint/145283/ (accessed Jun. 13, 2024).

[6] Ş. Başlık *et al.*, "ARO Based PID and FOPID Controller Design for AVR System." Accessed: Jun. 14, 2024. [Online]. Available: https://tok2023.itu.edu.tr/docs/librariesprovider68/bildiriler/25.pdf

[7] Y. Yu, "Performance Analysis of Automatic Voltage Regulator in Power Generation System," *International journal of science and engineering applications*, vol. 8, no. 7, pp. 180–185, Jul. 2019, doi: https://doi.org/10.7753/ijsea0807.1003.

[8] J. Aibangbee, "Voltages and Reactive Power Controls in Power System Network Using Automatic Voltage Regulator (Avr) and Static Var Compensator Methods," *IOSR Journal of Electrical and Electronics Engineering (IOSR-JEEE)* , vol. 11, no. 1, pp. 29–34, 2016, doi: https://doi.org/10.9790/1676-11122934.

[9] M. Ćalasan, Mihailo Micev, Milovan Radulović, A. F. Zobaa, H. M. Hasanien, and Shady, "Optimal PID Controllers for AVR System Considering Excitation Voltage Limitations Using Hybrid Equilibrium Optimizer," *Machines*, vol. 9, no. 11, pp. 265–265, Oct. 2021, doi: https://doi.org/10.3390/machines9110265.

[10] H. Zimmer, B. Niersbach, and J. Hanson, "Optimization of power plant AVR parameters to improve transient voltage stability," *2017 11th IEEE International Conference on Compatibility, Power Electronics and Power Engineering (CPE-POWERENG)*, Jan. 2017, doi: https://doi.org/10.1109/cpe.2017.7915147.

[11] Ch., G. Rao, B. Srikanth Goud, M. Bajaj, F. Jurado, and S. Kamel, "Combined Voltage and Frequency Control of Multi Area Power System using Sooty Tern Algorithm Optimized Cascade Controller," *2023 5th Global Power, Energy and Communication Conference (GPECOM)*, Jun. 2023, doi: https://doi.org/10.1109/gpecom58364.2023.10175786.

[12] H. T. Rishag, "Using Power System Stabilizers (Pss) And Shunt Static Var Compensator (Svc) For Damping Oscillations In Electrical Power System," *Semantic Scholar*, 2012. https://www.semanticscholar.org/paper/bb18c20473b979cdbec6abc9ede0e84f61711e4b (accessed Jun. 14, 2024).

[13] CH. Naga Sai Kalyan and G. Sambasiva. Rao, "Demonstrating the Effect of Excitation Cross Coupling and Communication Time Delays on Automatic Generation Control," *2021 4th Biennial International Conference on Nascent Technologies in Engineering (ICNTE)*, Jan. 2021, doi:

https://doi.org/10.1109/icnte51185.2021.9487779.

[14] M. Pacas, S. Villwock, P. Szczupak, and H. Zoubek, "Methods for commissioning and identification in drives," *Compel-the International Journal for Computation and Mathematics in Electrical and Electronic Engineering*, vol. 29, no. 1, pp. 53–71, Jan. 2010, doi: https://doi.org/10.1108/03321641011007966.

[15] J. Ortega Valenciano and I. Kortazar Astigarraga, "Virtual commissioning of an industrial production cell," Dissertation, 2023.

[16] W. Gu, "Commissioning generator AVR, PSS and model validation," in *2015 IEEE 28th Canadian Conference on Electrical and Computer Engineering (CCECE)*, May 2015. doi: https://doi.org/10.1109/ccece.2015.7129354.

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