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Stator Winding Load Elevation Control in Self-Excited Induction Generators

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Abstract

When the electrical demand is maintained at a consistent level by an Electronic demand Controller (ELC), a Self-Excited Induction Generator (SEIG) powered by a fixed-speed low-head hydroturbine may generate stable voltage and frequency. To manage frequency and regulate voltage in the Conventional-ELC (C-ELC), a chopper with a dump load is frequently employed in combination with consumer loads. Chopper action may put a lot of strain on the stator windings and excitation capacitors in a C-ELC system since the dump load is briefly connected to the winding during each chopping cycle and then disconnected. This stress may be reduced by introducing a new ELC topology. The major dump load now has two parts, as opposed to one as in the C-ELC. If some of the dump load is linked in parallel with the consumer loads, the stator windings and excitation capacitors will be put under less stress, and the SEIG will see less variation in the overall load. The proposed design may work with unbalanced consumer loads if applied per phase using bidirectional power switches. Simulations with unbalanced three-phase loads (with the use of bidirectional switches per phase) have shown that the proposed architecture can regulate voltage from no-load to full-load. Furthermore, the Total Harmonic Distortion (THD) investigation for output (stator) current shows a 9% enhancement when compared to the most current results in the literature.

Keywords: Insulated-Gate Bipolar Transistors (IGBTs), choppers, and exit capacitors are all part of microhydro.

Introduction

A significant portion of the world's population relies on traditional biomass for their everyday energy requirements, such as cooking, heating, and lighting, and a quarter of that population does not have access to electricity [1]. Particularly in developing countries, a high reliance on traditional biomass sources like wood may shorten the average lifespan due to the effects of several health problems [1]. A paradigm shift toward the use of alternative and renewable energy was driven by this motivation, together with growing environmental awareness, increasing electrical energy demand, decreasing supplies of conventional fuels, and technical breakthroughs in power electronics. Renewable energy sources including wind, pico-hydro, and micro-hydro turbines are ideal for remote areas without easy access to large-scale electrical generating services on the grid since they are stable and easy to install. Separate from the main electrical grid, these power plants are known as stand-alone power generating units.Ideal candidates for the squirrel cage self-excited induction generator (SEIG) [2-4] are standalone generating units with a power rating of less than 20kW driven by a constant speed uncontrolled turbine. The first account of the self-excitation phenomenon was provided by Besant and Potter [5] in a local bank of capacitors across the output terminals of an induction generator.

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Compared to DC generators or wound rotor induction generators, SEIGs have many benefits, such as a lower unit cost per generated kilowatt, greater durability, no brushes, easier maintenance, and self-protection under fault conditions [6,7]. On the other hand, SEIGs aren't very good at controlling voltage and frequency. This has led to a plethora of research aimed at overcoming these constraints in the last few decades [8]. Variations in consumer loads or mechanical power supplied by the primary mover will cause the SEIG's output voltage and frequency to vary. In remote mountain areas, where penstock fed hydro turbines mitigate the effects of fluctuations in mechanical power delivery, continuous load power allows for voltage and frequency regulation.

To keep the load power consistent, you may employ a variable or moveable dump load. A variable or adjustable dump load should be connected in parallel with consumer loads to maintain a constant overall load. The use of electronic load controllers (ELCs) allows the hydro turbine to maintain a consistent total power output. Although VAR sources for voltage regulation are theoretically feasible [7–13], their complexity and high cost make them impractical for use in pico or micro size producing units. Thus, several ELCs for SEIGs have been recorded by researchers over the last twenty years [4, 14–23], and we will go into each of them in further detail below. Earlier works on this subject were by Bonert and Hoops [14]. A method for controlling impedance was laid forth. Assembling an unregulated three-phase rectifier, a dump load, and a chopper switch in series enables voltage regulation. By aligning the helicopter with the sixty-degree conduction intervals of the bridge, the voltage distortion is reduced to a minimum. The feasibility of controlling asymmetrical loads and an automated generator start-up mechanism were later described by Bonert and Rajakaruna [15]. There was a brief investigation of this method by Singh [16]. Lastly, the method's unregulated rectifier, chopper, and dump load were designed in detail by Singh, Murthy, and Gupta [2]. With just one power switch, this system is simple, cheap, and reliable, but it can only handle the imbalanced three-phase loads that generators in less densely populated regions, such as rural or suburban areas, can handle. Three methods were proposed by Smith [17] according on the induction generator's intrinsic characteristics. Several voltage control methods were created, such as those that use binary weighted switching resistors, a chopping scheme with a programmable mark-space ratio, and phase angle control.

Due to its variable lagging power factor, the SEIG could encounter issues when using the phase angle control approach. Discrete control of output power and complexity in connecting the power electronic switches are the main drawbacks of the binary weighted switched resistor technique. A simplified version of the impedance controller approach [14] developed for a single-phase system is used by the variable mark-space ratio technique. Mathematical models of SEIGs with improved ELCs have been presented, as stated by Singh [18]. An improved ELC was created by integrating a high frequency DC chopper with a current controlled voltage source inverter that relies on three Insulated Gate Bipolar Transistors (IGBTs). In order to maintain balanced generator currents, the improved ELC produces compensating currents in the event of unbalanced loads. A voltage regulator for unbalanced three-phase loads might be made from the improved ELC, despite the complexity of the proposed control method. In contrast, a newly constructed phase locked loop circuit and a voltage source converter devoid of a chopper are used for a slightly different approach in [19]. A more exact localization of the rotor flux was achieved by means of the control method, which included the induction machine's magnetizing curve. Several control mechanisms, each with its own unique twist, have been reported in the literature based on the architecture outlined in [19]. In [20], one method is proposed for controlling the terminal voltage by modifying the converter's modulation index in response to changes in consumer loads-induced variations in DC capacitor voltage.

System and Induction Generator

Creating models A d-q frame induction generator's (IG) equivalent circuit is shown in Figure 1. Using MathWorks's

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MATLABSIMULINK and the modeling approach outlined in [25], we construct a modular Simulink model in the stationary reference frame. In order to simplify the simulation, a common matrix formulation has been used, which is based on the method given in [26]. The following matrix equations, expressed as state space equations, are used for transient analysis of the three-phase SEIG.

$$\dot{x} = Ax + By$$

where $x = [i_{ds}, i_{qs}, i_{dr}, i_{qr}, V_{dL}, V_{qL}, i_{dL}, i_{qL}]^T$, $y = [V_{ds}, V_{qs}, V_{dr}, V_{qr}]^T$, $\dot{x} = \frac{dx}{dt}$

$$A = K\begin{bmatrix} R_sL_r & -\omega_rL_m^2 & -R_rL_m & \omega_rL_rL_m & L_r & 0 & 0 & 0 \\ \omega_rL_m^2 & R_sL_r & \omega_rL_mL_s & -R_rL_m & 0 & L_r & 0 & 0 \\ -R_sL_m & \omega_rL_rL_m & R_rL_s & \omega_rL_sL_r & -L_m & 0 & 0 & 0 \\ -\omega_rL_mL_s & -R_sL_m & -\omega_rL_sL_r & R_rL_s & 0 & -L_m & 0 & 0 \\ 1/CK & 0 & 0 & 0 & 0 & 0 & -1/CK & 0 \\ 0 & 1/CK & 0 & 0 & 0 & 0 & 0 & -1/CK \\ 0 & 0 & 0 & 0 & 1/LK & 0 & -R/LK & 0 \\ 0 & 0 & 0 & 0 & 0 & 1/LK & 0 & -R/LK \end{bmatrix}, B = K\begin{bmatrix} -L_r & 0 & L_m & 0 \\ 0 & -L_r & 0 & L_m \\ L_m & 0 & -L_s & 0 \\ 0 & L_m & 0 & -L_s \\ 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 \end{bmatrix}$$

$$K = \frac{1}{(L_m^2 - L_rL_s)}$$

Proposed Electronic Load Controller

Proposed ELC topology

As shown in Figure 3a, a standard system consists of the following components: a prime mover, an induction generator, an excitation capacitor bank, three-phase unbalanced loads, electronic load controllers, and the control circuits that link them. These components collaborate to provide gate signals for the IGBT switches that are used. The anticipated ELC structure is shown in Figure 3b across all stages. You can see a comparison between the topology in [4] and the one in Fig. 3c. A chopper switch is the main element of the ELC in the proposed design. A better switch () has replaced the chopper switch in the schematics. It should be noted that in experimental and simulation research, bidirectional IGBT switches should be employed instead of this ideal switch [4, 23]. The ELC in the suggested design consists of a chopper switch, two series resistances, and a single-ended circuit. It is possible to connect a portion of the dump load in parallel with the consumer loads while the chopper switch is closed. For clarity's sake, Fig. 4 shows the analogous circuit of the chopper switch in this configuration. Here, with the chopper switch off, the total dump load is, and with the chopper switch on and the ELC connected to the system, it grows to. Figure 4(a) and (b) depict these two possibilities. Figures 4c and d show the same circuit diagram of the method proposed in [4]. In the method proposed by Ramirez [4, 23] and in all ELC approaches that involve chopper and dump loads, the dump load is not connected to the induction generator when the chopper is off (Fig. 4c). However, in the proposed topology, a small non-zero dump load is connected to the system (Fig. 4a), leading to a more uniform generated power and reducing machine stress. Following is an explanation of the procedure used to develop the proposed ELC.

Experiment Outcomes

Results from a simulation study investigating the feasibility and efficiency of the proposed ELC are shown here. The proposed ELC design was used to model the voltage control of a 3 kW, 220V Donly IG in MATLABSIMULINK. A 316 rad/s driving speed was applied to the selected IG using a 60 three-phase star-connected excitation capacitor bank that was charged to 10V, 10V, and -20V as starting voltages. Both the voltage and frequency of the generator's outputs level out at. The two sudden changes in the three-phase unbalanced consumer loads used in this simulation are summarized in Table 1. The consumer load and the predicted ELC are both connected to the generator at. At and, there are two separate changes made to the loads that consumers are expected to pay. Figure 5 displays the recommended ELC's regulated output voltage, magnetizing current, root-mean-square (RMS) value, instantaneous generated power (both with and without ELC), and instantaneous output voltage. Sections (a) and (b) show the current and magnetic inductance, respectively, in this figure. The RMS output voltage is shown in Figure 5c both with and without the ELC. The proposed ELC brings the system's voltage fluctuations down to around 4 V RMS, or 1.8%. Fig. 5c displays the transient voltage's amplitude. Under steady-state conditions, the output voltage's root-mean-square (RMS) variance is less than 1%. The output voltage has a standard variation of 31 V RMS (248 minus 217) in the absence of active load regulation (ELC). The three-phase output power with the proposed ELC is shown by the black lines in Fig. 5d, while the power without it is represented by the gray lines. Table 1 shows a

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three-phase unbalanced load pattern, which means that even at steady state, the IG without ELC may produce power ranging from 0.2 to 3.05 kW. These results demonstrate that the proposed ELC design can control frequency, regulate voltage, and draw the rated power from the IG, even in an unbalanced system. Two separate ELCs and the consumer current make up the three-phase instantaneous currents seen in Figures 6 and 7. Figure 7 shows the ELC current for one full cycle under three different load conditions. After dumping power, total power, and imbalanced consumer loads are taken into consideration, Figure 8 displays the average power for each phase. In all, each process consumes around 1 kilowatt of power.

Table 1. The considered consumer load pattern with two step changes at 5.5 seconds and 8.5 seconds.

Consumer loads				
Connection Time (S)	0-1.5	1.5-5.5	5.5-8.5	8.5-12
Phase "a" load (Ω)	NL	1000	230	75
Phase "b" load (Ω)	NL	1200	300	63
Phase "c" load (Ω)	NL	800	160	61.5

Figure 9 shows typical dump load currents for the two topologies, along with other information, so that we may compare the proposed ELC to the one in [4]. Figures shown in the second column (right hand side) are simulation results based on [4], whereas the first column displays the dump load current based on the suggested architecture. The consumer loads used for this study are three phase star-connected loads with values of 55, 95, 150, and 300 Ω. The present dump load may only be between two sinusoidal waveforms in the suggested manner. Figures 9e–9h show the top sinusoidal waveform and zero, which are the equivalent bounds for the approach described in [4]. With a comparable setup to Figure 9, Figure 10 shows the harmonic content of the stator current based on the suggested technique and that in Figure 4. Every instance's Total Harmonic Distortion (THD) is shown. Compared to the topology in [4], the suggested topology has a lower THD. When compared to various topologies that have been suggested, the one in [4] has the lowest total harmonic distortion (THD) level. Our suggested solution primarily aims to decrease the THD level by reducing the dump load current variations. Figure 11 shows the difference in THD level between the suggested ELC topology and the one in [4]. We can see the THD as a function of the load current utilized each phase. Shown in (a) is the stator current THD, and in (b) is the output voltage THD. In contrast to the THD of 45.5% in [4], the maximum THD for the output current of the suggested topology is around 36%. There is a close relationship between the two topologies in terms of the computed THD for the output voltage.

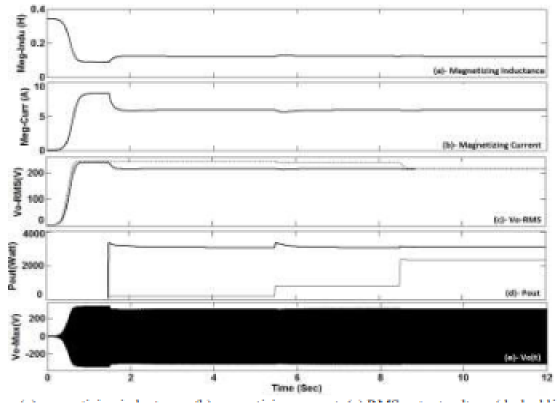

Fig. 1. Typical system characteristics, (a) magnetizing inductance, (b) magnetizing current, (c) RMS output voltage (dashed line: no ELC; black line: with proposed ELC) , (d) output power with (gray) and without ELC (black), and (e) instantaneous output voltage with proposed ELC.

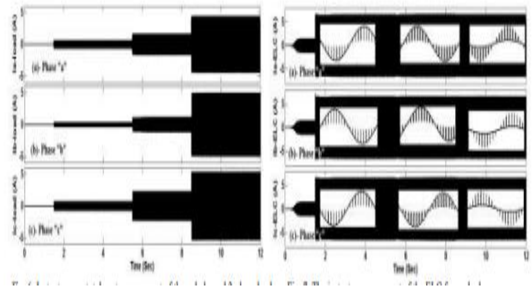

Fig. 2. Instantaneous total customer current of the unbalanced 3-phase load Fig. 7. The instantaneous current of the ELC for each phase.

Conclusion

Our research presents a novel and straightforward Electronic Load Control system for small hydroelectric dams. The induction generator is what they use. It is the fundamental goal of the proposed method to lessen load on the generator's stator windings. An innovative chopper circuit design was created to achieve this. The results of the simulations demonstrate that the suggested ELC performs well across the board for consumer loads, even those with imbalanced three-phase loads. Because fewer power switches are needed (3 bi-directional power switches compared to 7 uni-directional power switches), it is more cost-efficient and reliable than ELC designs based on rectifier or converter architectures. Reducing stress on the stator may also enhance the induction generator's longevity.

References

[1] "Renewable energy village power system for remote and impoverished Himamayan villages in Nepal" by Z. Alex, H. M. Kimber, and R. Komp. Paper presented at the 2006 International Conference on Renewable Energy for Developing Nations

In March 2006, B. Singh, S. S. Murthy, and S. Gupta published an article in the IEEE Transactions on Energy Conversion titled "Analysis and design of electronic load controller for self-excited induction generators." The article can be found on pages 285–293.

the third Voltage and frequency of self-excited slip-ring induction generators, by T. F. Chan, K. A. Nigim, and L. L. Lai, published in March 2004 in the IEEE Transactions on Energy Conversion, volume 19, issue 1, pages 81–87.

[4] "An electronic load controller for the self-excited induction generator" (J. Ramirez and E. Torres, 2007) published in the IEEE Transactions on Energy Conversion, volume 22, issue 2, pages 546–548.

The paper "Capacitor excitation for induction motors" was published in May 1935 in the AIEE Transactions, volume 54, pages 540-545, and was written by E. D. Besant and F. M. Potter.

In his article titled "Three-phase self-excited induction generators: an overview," R. Bansal published in June 2005 by the IEEE Transaction on Energy Conversion, volume 20, issue 2, pages 292-299

IEEE Transactions on Industrial Electronics, volume 53, issue 5, pages 1437–1452, October 2006, by B. Singh, S. S. Murthy, and S. Gupta, "STATCOM-based voltage regulator for self-excited induction generator feeding nonlinear loads."

IEEE Transactions on Industry Applications, vol. 46, no. 2, pp. 720-730, Mar/Apr 2010, by Y. K. Chauhan, S. K. Jain, and B. Singh, "A prospective on voltage regulation of self-excited induction generators for industry applications."

IEEE Transactions On Industry Applications, vol. 46, no. 4, pages 1271-1280, July/August 2010, by B. Singh, M. Singh, and A. K. Tandon, "Transient performance of series-compensated three-phase self-excited induction generator feeding dynamic loads."

"Effect of long shunt and short shunt connections on voltage variations of a self-excited induction generator," [10] L. Wang and J. Y. Su, Volume 12, Issue 4, Pages 368–374, December 1997, IEEE Transactions on Energy Conversion.

[11] "Terminal voltage regulation characteristics by static VAR compensator for a 3-phase self-excited induction generator," published in the July/August 2004 issue of the IEEE Transactions on Industry Applications, is written by T. Ahmed, O. Noro, E. Hiraki, and M. Nakaoka.

[12] Published in the March 2005 issue of the IEE proceedings on Generation Transmission and Distribution, the article "Static VAR compensator-based voltage control implementation of single-phase self excited induction generator" by T. Ahmed, K. Nishida, and M. Nakaoka delves into the topic.

in [13] An analysis and design of a voltage regulator for a self-excited induction generator based on STATCOM was published by B. Singh, S. S. Murthy, and S. Gupta. December 2004 issue of the IEEE Transactions on Energy Conversion, volume 19, issue 4, pages 783-790.

At the 1989 IEEE Power Engineering Society Summer Meeting, R. Bonert and G. Hoops presented a paper titled "Stand alone induction generator with terminal impedance controller and no turbine controls" (pp. 28-31).

In 1990, R. Bonert and S. Rajakaruna published an article in the IEEE Transactions on Energy Conversion titled "Stand alone induction generator with terminal impedance controller and no turbine controls." The article may be found on pages 33–39.

IEEE Transactions on Industry Applications, vol. 41, no. 5, pp. 1194-1204, September/October 2005, B. Singh, S. S. Murthy, and S. Gupta, "Transient analysis of self-excited induction generator with electronic load controller (ELC) supplying static and dynamic loads."

[17] The paper "Induction generators for stand alone micro - hydro systems" was presented at the 1996 IEEE International Conference on Power Electronics, Drives and Energy System For Industrial Growth and can be found on pages 669-673.

[18] An improved electronic load controller for self-excited induction generator in micro-hydel applications, by B. Singh, S. S. Murthy, and Sushma Gupta, published in the 2003 IEEE Industrial Electronics Society (ECON) conference proceedings (vol. 3, pp. 2741 - 2746), held from November 2-6, 2003.

The year 19 "Advanced control of PWM converter with variable-speed induction generator" was published in July/August 2006 in the IEEE Transactions on Industry Applications by T. Ahmed, K. Nishida, and M. Nakaoka.

[20] "A new method for voltage and frequency control of stand-alone self-excited induction generator using PWM converter with variable DC link voltage," 2008 American management Conference, Seattle, Washington, USA, June 11-13, 2008, pages 2486- 2491, by K. H. Youssef, M. A. Wahba, H. A. Youssef, and O. A. Sebakhy.

[21] "Voltage source inverter for voltage and frequency control of a stand-alone self-excited induction generator," presented by H. S. Timorabadi and E. S. Rogers at the 2006 IEEE Canadian Conference on Electrical and Computer Engineering (CCECE 2006) in Ottawa, May, pages 2241-224 [22] The paper "Novel voltage controller for stand-alone induction generator using PWM-VSI" was presented at the 2006 IEEE Industry Application Conference in Tampa by G. V. Jayaramaiah and B. G. Fernandes and can be found on pages 204–208.