Grid-Connected Wind Energy Conversion System Voltage Profile Improvement Using SVC Compared with VSC by Reducing Voltage Flicker

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ABSTRACT

Aim: The main aim of the research is about improving the voltage profile in Grid-connected Wind Energy Conversion Systems. The comparative analysis on voltage profile minimization in the Grid-connected based Wind Energy Conversion System (WECS) is done by using Innovative Static Var Compensator (SVC) compared with Voltage Source Converter (VSC). The switches involved in both FACTS controlling devices are controlled by aGrid optimization controller. **Materials and Methods:** SVC and VSC controllers are implemented in Grid-connected WECS to analyze the improvement of voltage profile under a wind speed of 12m/s. The sample size has been calculated using G power software and it has 14 samples for both groups. The significance value is determined as 0.003 ($p<0.05$, statistically significant) based on SPSS analysis. **Results:** Based on the results obtained it is inferred that the SVC controller based Wind Energy System has better voltage profile 80.05% when compared to VSC 70.89%. **Conclusion:** Voltage profile-based Grid-connected wind energy system using SVC controller provides better voltage profile improvement when compared to VSC employing Grid optimization controller for the selected date.

Keywords: Static Var Compensator,Innovative Voltage Source Converter, Voltage Flicker, Grid-connected Wind Energy Conversion System, Green Energy, Voltage Profile, Wind Energy Conversion System, Grid optimization controller.

INTRODUCTION

The main aim of the research is to analyze the improvement of Voltage profiles in Grid-connected Wind Energy Conversion Systems by using SVC based Grid-connected WECS (Lahaçani, Aouzellag, and Mendil 2010; Savić and Đurišić 2014)). With a change in load the voltage Level drops, which increases the reactive power (Savić and Đurišić 2014). The main purpose is to improve the voltage profile by reducing the reactive and real power loss in the Grid-connected wind energy system (Pandey and Bag 2015). The voltage profile in the system is being improved by using SVC technology with Grid optimization controllers for voltage enhancement, reducing system losses, suppression of fluctuations (Chopade et al. 2011). Applications are used to regulate the Grid voltage, reduce net power loss, damping the power oscillations ("SVC Applications" 2010; Abu-Siada, Shahnia, and Shiddiq Yunus 2017).

The number of articles published is 16 (IEEE - 02; Google Scholar - 14), the most cited articles are Grid-connected Power Loss Reduction (Daealhaq, Kfajey, and Tukkee 2021) and Voltage Profile Improvement Using Optimal the Placement of FACTS Devices to reduce power loss and improve voltage profile (Pandey and Bag 2015). A comparative study on UPFC and SVC towards voltage profile improvement of a Grid-connected distributed generation system improving the reliability of the power supply and enlargement of the power system capacity. (Krost and Bakare, n.d.) Author has proposed a method for Voltage profile improvement in microgrid PV units using genetic algorithm optimal control of distribution voltage using DGs characteristics. (Lahaçani, Aouzellag, and Mendil 2010) Author contributes to the improvement of voltage profile in an electrical network with a wind generator using a Innovative Static Var Compensator device that maintains voltage stability and controls the reactive power. Based on the above research, UFFC based wind form in green energy provides a better Voltage Profile improvement method in Grid-connected WECS. (Parakh et al. 2020; Pham et al. 2021; Perumal, Antony, and Muthuramalingam 2021; Sathiyamoorthi et al. 2021; Devarajan et al. 2021; Dhanraj and Rajeshkumar 2021; Uganya, Radhika, and Vijayaraj 2021; Tesfaye Jule et al. 2021; Nandhini, Ezhilarasan, and Rajeshkumar 2020; Kamath et al. 2020)

In the existing methods, voltage profile improvement is not carried out efficiently as it has high voltage flicker. This research work is to improve the voltage profile of the Wind Energy Conversion system by using SVC based on the source voltage with a Grid optimization controller. The Voltage Profile reduction technique is implemented within the SVC controller by way of optimizing the error difference at the output source current.

MATERIALS AND METHODS

This project was completed in the Power Electronics Lab, Saveetha School of Engineering, SIMATS. The sample size was established based on previous research. Because no human or animal samples are utilized in this study, no ethical approval is necessary. G Power software is used to calculate the sample size using two algorithms. Based on this 7 samples are required for each group so a total of 14 samples (g power setting parameters: Statistical test difference between means α - 0.05, Voltage Flicker - 80.05%, effect size - 1.4142136, mean SVC - 1.4634, mean VSC - 1.0021, sd - 0.0069)(Maegaard 2009). The system is simulated using the MATLAB© Simulink model.

Wind Energy Conversion System (WECS)

Wind energy conversion system converts kinetic energy into mechanical energy. The fundamental factor on the mechanical assembly is the gearbox, which transforms the slower rotational speeds of the wind turbine to greater rotational speeds of the electric generator side longevity. (Mittal, Sandhu, and Jain 2011) A Grid-connected wind turbine can reduce the consumption of utility-supplied electricity for lighting and wind power can produce renewable energy. The green energy system conversion system is a complex system converting wind energy to rotational energy then to electric energy. So to the electricity distribution system, a small

Grid-connected wind energy system can be connected and the output power or torque of a wind turbine is determined by several factors like wind velocity, Voltage Profile reduction technique, size or shape on the turbine, etc. For the dynamic model of the wind turbine, the parameters that are involved are to understand the behavior of a wind turbine over the region of its operation. The added device is an (inverter) power conditioning unit that makes the turbine output electrically compatible with the utility Grid, batteries are usually not required.

Static Var compensator (SVC)

The Static Var Compensator is a technique for increasing the power factor. The power factor lags whenever an inductive load is connected to the transmission line due to the lagging load current. A shunt capacitor is connected to compensate for the drawing current from the source voltage. The power factor improves as a result of this. This sort of rectifier is commonly seen in microturbines and wind turbines (Rostami 2012). It's utilized in Grid-connected Wind Energy Conversion Systems to improve voltage profile and lower voltage flicker employing Grid optimization controllers. The voltage at the SVC's terminals is controlled, which controls the amount of reactive power injected or absorbed into the power system. TheInnovative Static Var Compensator provides reactive power when the system voltage is low (SVC capacitive). Reactive power is absorbed when the system voltage is high (SVC inductive). Another advantage of SVC is its ability to overcome great distances not only between the wind frame and the load centers but also inside the wind frame itself. As multiple wind farms span tens to many miles in length, power plant collector Grid topologies will become preventive in terms of power issue capability, utility and maintenance. In such cases, the reactive losses of the generator increase transformers (GSU) collector Grid electrical resistance and plant power electrical devices may limit the inherent reactive power capabilities of wind turbines as a green energy source.

Voltage Source Converter (VSC)

By using a VSC connected to the Grid, it is possible to install more wind power at the existing Grid compared to the case where fixed speed wind turbines are installed (Kalunta and Ngwu 2021). These additional features change the power of the wind and cause only a moderate increase in the VSC rating. By using VSC future Grid quality problems can be avoided. With the high growth of rapid change valve power ratings, the use of Innovative Voltage Source Converter is increasing in wind power Applications used in green energy. A very small phase filter is required for a specific current harmonic content if VSC is used instead of a thyristor inverter with Grid optimization controller for controlling the switches. Further Innovative Voltage Source Converters can create an option for power factor and energy flow in both directions. Another advantage is that stall control can easily change the starting problem of the wind turbine's energy flow.

Statistical Analysis

SPSS software was used to do statistical analysis on SVC and VSC networks. The independent variable is voltage flicker while the dependent variable is voltage Profile. To estimate the gain Independent T test analysis is carried out.

RESULTS

The voltage Profile improvement using SVC 80.05% is better when compared to VSC 70.89 %. The SVC is simulated using MATLAB/SIMULINK and simulation results show the Grid voltage and current that is in phase, making the power thing unity which implies up to expectation the reactive power demand over the Induction generator and load are no longer, fed by using the Grid rather it is supplied by the SVC.

In Table 1 there is minimal voltage profile improvement in SVC controller-based WECS as compared to Innovative Voltage Source Converter controller-based WECS. Values are noted for different sampling times under a wind speed of 12m/s.

Table 2 shows t-test comparisons of SVC and VSC controllers for different sampling times. The mean value of VSC 1.0021 is high and the mean value of the SVC 1.4634 is low. The standard deviation of both controllers is 1.2456 SVC and 0.0069 VSC.

Table 3 displays the independent-samples T-test for the two algorithms and observed significant differences in power. The quality significance variation among the two groups is 0.003 ($p < 0.05$, statistically significant).

Figure 1 and 2 represents Voltage profile improvement in the Grid by injecting VSC and SVC. Figure 3 represents a comparison bar chart of the two algorithms estimating that the SVC algorithm provides less power loss than the VSC algorithm.

DISCUSSION

SVC and VSC controllers have been implemented in Grid-tied WECS and the power quality is analyzed. From the findings, it is evident that SVC controller-based WECS has a lower power loss than Voltage Source Converter.(Mittal, Sandhu, and Jain 2011) By analyzing the High Voltage Flicker of the Wind Energy conversion system using SVC and VSC. The high Voltage Flicker of SVC was less when compared to VSC. So the Voltage Profile reduction technique improvement using SVC is better at 1.445% than VSC 1.001%.

From the literature, most of the authors cited SVC so this method is better for Voltage Profile improvement in wind energy conversion systems. FACTS devices are typically utilized in transmission control, while bespoke power devices are typically employed in distribution control. (Pandey and Bag 2015) Devices such as the Unified Power Flow Controller (UPFC), Innovative Static Var Compensator, Dynamic Voltage Restorer (DVR), solid-state transfer switch, and solid state fault current limiter have been created since the advent of FACTS and the custom power concept (Enslin, n.d.; Singh, Al-Haddad, and Chandra 1999). These devices advanced control and improved semiconductor switching have ushered in a new era of power quality mitigation. (Rostami 2012)By analyzing the High Voltage Flicker of the Wind Energy conversion system using SVC and VSC. (Pandey and Bag 2015) The high Voltage Flicker of SVC was less when compared to SVC. So the Voltage Profile improvement using STATCOM is better (Betha, Satish, and Sahu 2017).

The research has described the effectiveness of these VSC is to control scheme for the Grid-connected wind energy generation system to improve the voltage profile. (Lahaçani, Aouzellag, and Mendil 2010) contribution to the improvement of voltage profile in electrical network with wind generator using SVC device devices in power quality mitigation, such as sag compensation, harmonic removal, imbalance compensation, reactive power compensation, power flow management, power factor correction and flicker reduction has been investigated (Xu et al., n.d.; Arnez and Zanetta, n.d.; Pohjanheimo and Lakervi, n.d.; Anaya-Lara and Acha 2001; Masdi et al., n.d.). These devices were designed to address certain power quality issues. For example, UPFC is effective at controlling power flow. For voltage sag correction DVR is utilized which serves as a series compensator. SVC a shunt compensator is used to compensate for reactive power and voltage sag. The SVC and DVR are only effective for compensating a certain sort of power quality problem. So a new form of universal series shunt compensator (USSC) is needed to minimize a variety of power quality issues (Hannan and Mohamed, n.d., 2005). It is feasible to adjust for a range of power quality problems in a distribution system utilizing a unified approach of series-shunt compensators, including voltage sag compensation, swell compensation, imbalance voltage mitigation and flicker reduction.

The limitations of the study are due to variations in meteorological data such as wind speed and failures of electronic and mechanical components of the wind turbines (Daealhaq, Kfajey, and Tukkee 2021) Voltage Flicker emission is dramatically increased in the Grid-connected wind farm (Samet et al. 2021b). In terms of economic and technological considerations, the Innovative Static Var Compensatorhas been deemed the primary technology for reducing Voltage Flicker emission. The SVC on the other hand has a built-in delay due to switching limits induced by thyristor ignition delay (Samet et al. 2021a). The data simply shows that all of the FACTS described here can improve the voltage stability and response to transient Grid failures of fixed speed wind farms compared to when they are not deployed. SVC and VSC improve voltage stability at wind farm rectifier output in the face of wind speed changes.

CONCLUSION

Based on the obtained results it is inferred that the Voltage Profile reduction technique improvement in a Grid-Connected Wind Energy Conversion System using SVC is better than VSC. A system using SVC modulation provides 80.05% compared with the VSC modulation provides 70.89%. This work observes that the Static Synchronous Compensator is better than Static Var Compensator. Therefore by reducing the harmonics the efficiency is increased. Based on the independent T test the significance value is 0.003 ($p < 0.05$) statistically significant within the limit of study.

DECLARATIONS

Conflict of Interests

The submission has no potential conflicts.

Authors Contribution

Data collection, data analysis and manuscript preparation were all done by author BSM. Conceptualization, data validation and critical assessment of papers were all done by author LM.

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TABLES AND FIGURES

Table 1. Comparison of power loss in Grid-tied WECS using VSC and SVS controller

Inductive reactive power (Watts)	**Voltage Flicker (Volts)**	
	VSC	**SVC**
1000	1.001	1.445
950	1.002	1.437
900	1.003	1.369
850	1.003	1.267
800	1.002	1.518
750	1.002	1.572
700	1.002	1.636

Table 2. Statistical analysis of VSC and SVC controllers. Mean power loss value, Standard deviation and Standard error mean values are obtained for 07 samples each. It is observed that SVC has better performance than VSC. The average voltage profile value of the recommended method is (1.4634), which is lower than the average value of (1.0021) for normal systems.

Group Statistics					
	GROUP NAME	**N**	**Mean**	**Standard Deviation**	**Standard Error Mean**
Voltage Flicker	VSC	7	1.0021	0.0069	0.0026
	SVC	7	1.4634	1.2456	0.4708

Table 3. Independent sample t-test for significance and standard error determination. Since the value of significance is 0.003 ($p < 0.05$) which is considered to be statistically significant.

Independent Sample Test										
Levene's Test for Equality of Variances				**T-test for Equality of Means**						
		F	Sig.	T	Df	Sig. (2-tailed)	Mean Difference	Std. Error Differences	95% Confidence Interval of the Difference	
									Lower	Upper
Voltage Flicker	Equal Variances assumed	3.334	0.003	-9.798	12	.0000	-0.46129	0.04708	56386	35871
	Equal Variances not assumed			-9.798	0.000	0.000	-0.46129	0.04708	57648	34609

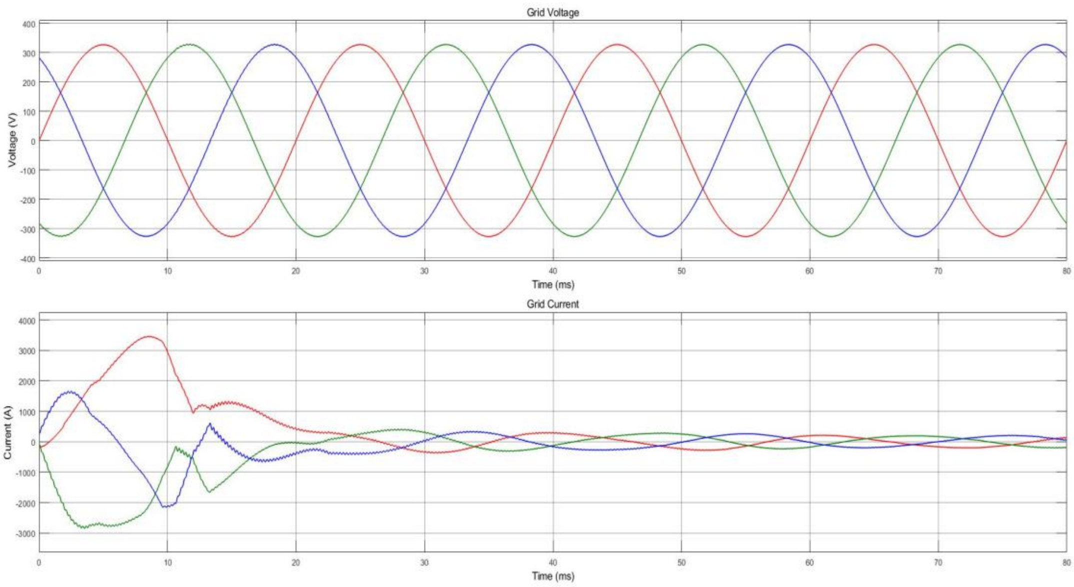

Fig.1. Voltage profile improvement in Grid by injecting VSC. X-axis represents improved Grid voltage and current of VSC. Y-axis represents time in seconds (S).

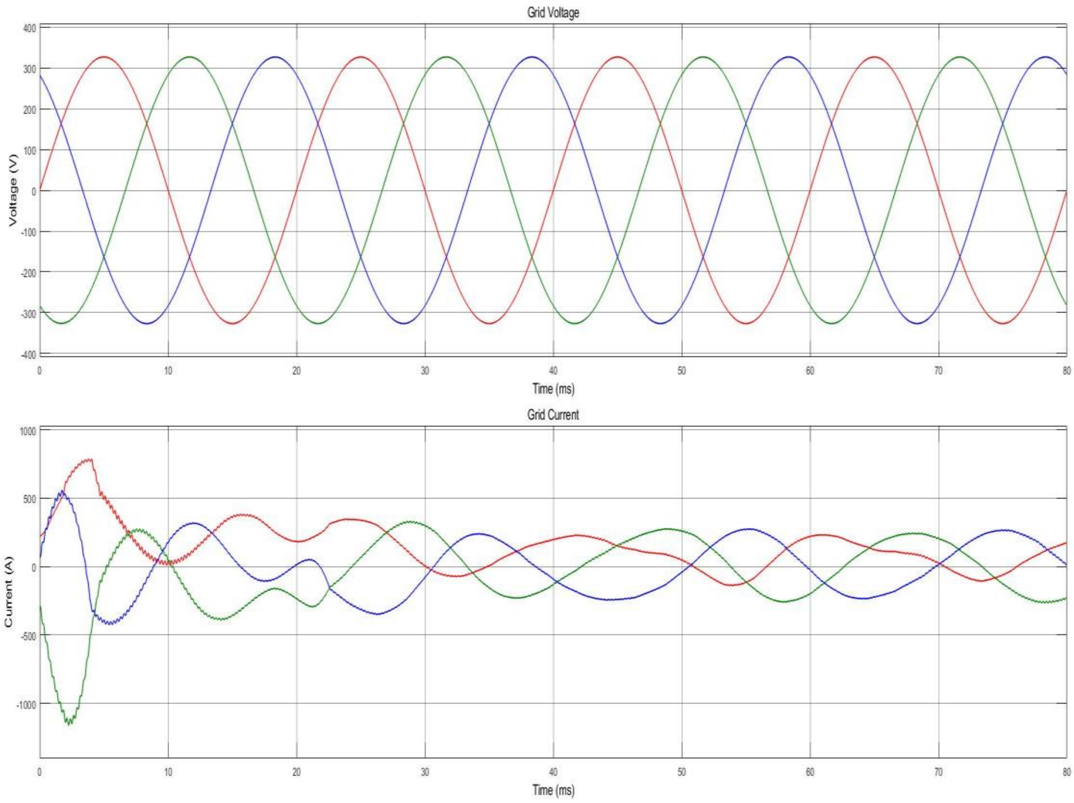

Fig. 2. Voltage profile improvement in Grid by injecting SVC. X-axis represents improved Grid voltage and current of SVC. Y-axis represents time in seconds (S).

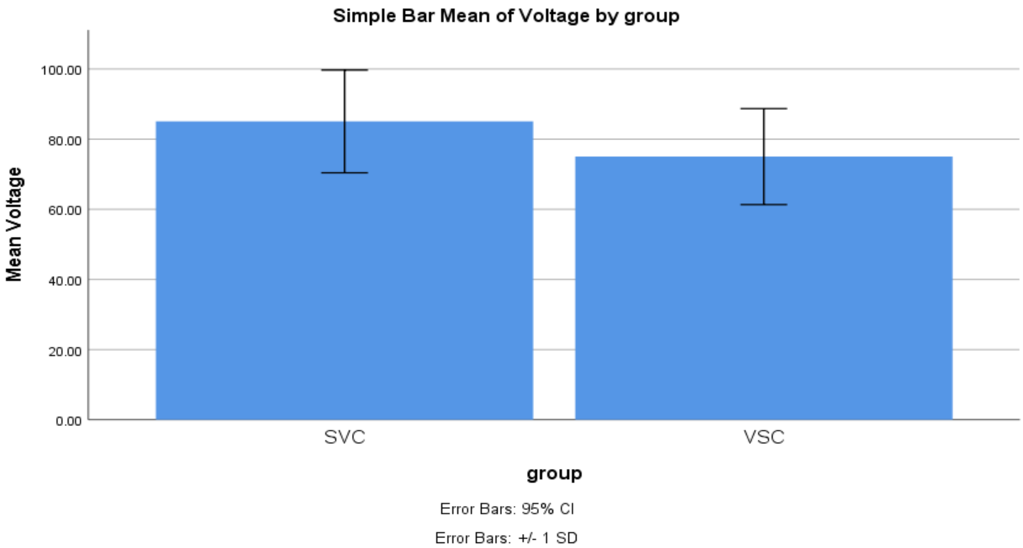

Fig. 3. Comparison of SVC and VSC controllers in terms of mean Voltage Flicker. The mean Voltage of SVC is less than the VSC controller and the standard deviation of SVC is more than VSC. X-Axis: VSC Vs SVC controller Y-Axis: Mean Voltage Flicker ± 1 SD.