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# Voltage Profile Improvement of Grid-Connected Wind Energy System Using STATCOM Compared with SVC by Limiting Voltage Flicker

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**Abstract**

**Aim:** The research's primary goal is to improve voltage profiles in grid-connected wind energy systems. The comparative analysis on voltage profile minimization in the Grid-connected based Wind Energy Conversion System (GCWECS) is done by using voltage profile techniques such as Innovative Static Synchronous Compensator (STATCOM) and compared with Static Var Compensator (SVC). **Materials and Methods:** The intrusion of STATCOM and SVC in GCWECS is defined with each system possessing seven sample values and a G power is implemented to analyze the efficiency. Parameters considered are CI, alpha. The significance value is determined as 0.041 ($p<0.05$, statistically significant) based on SPSS analysis. **Results:** From observation, it is evident that the STATCOM controller 0.33% based WECS has a minimum voltage loss than the SVC 0.23%. **Conclusion:** The voltage profile based grid-connected wind energy system using a voltage profile technique named as STATCOM provides better voltage profile improvement when compared to SVC for the selected data.

**Keywords**

Innovative Static Synchronous Compensator, Static Var Compensator, Voltage Profile, Grid-Connected Based Wind Energy Conversion System, Green Energy, High Voltage Flicker, Wind Energy Conversion System, voltage profile technique.

## INTRODUCTION

Electricity consumption has risen in recent times due to the demographic development of the industry. As a result, electricity production may become a major concern shortly. Power generation can come from both renewable and nonrenewable sources. As a result of the continued use of coal and natural gas to generate electric power, global warming, air pollution, and the depletion of fossil fuels are all rising, as is their price. As a result, renewable energy sources (RES) must be considered as future electricity sources. Between all sustainable energy sources of electricity, wind energy generation is the most cost-effective and durable (Arunkumar, Kannan, and Selvalakshmi 2016). Wind turbines are considered to be green energy that is synchronized with the grid and could likewise be used to produce power. As a result, integrating renewable energy into the grid is critical. This reduces the generation's environmental impact (Diedrichs, Beekmann, and Kruse 2012; Lahaçani, Aouzellag, and Mendil 2010). In recent years, there has been an increase in the use of wind generation systems. Wind turbines produce very little electricity, with individual units generating up to 5 MW (Rahman and Tiwari 2016). The most widely employed RES in power systems is wind power generation (Das et al. 2011). Voltage sag/swell, voltage flicker, harmonics are all issues that arise during the connecting of a wind turbine to the grid (Pati et al. 2015).

Various studies have been conducted in order to develop strategies for the continued existence of the Wind Energy Conversion System in such fault environments (Rostami 2012). The number of articles published-16 (IEEE-07; GoogleScholar-09), To improve the low voltage ride through (LVRT) performance of WECS employing Innovative Static Synchronous Compensator under single-phase and three-phase failure situations for the Spanish grid system, research was done. In (Singh et al. 2018; Truong, Ngo, and Thi 2017), a quick response was reached for defeating voltage loss in the early phases of the process in a fault state, but completely lowering the voltage drop to the minimum voltage level took significantly longer than the algorithm's initial quick turnaround of Voltage Profile Technique. various Voltage Profile issues were investigated in (Kuang et al. 2019; Mukhopadhyay and Mandal 2016; Panda, Satpathy, and Paul 2011; Singh et al. 2018), including progressive voltage shifts, fast voltage instability, harmonics, voltage dips, and sags, and so on.
Previously our team has a rich experience in working on various research projects across multiple disciplines (Venu and Appavu 2021; Gudipaneni et al. 2020; Sivasamy, Venugopal, and Espinoza-González 2020; Sathish et al. 2020; Reddy et al. 2020; Sathish and Karthick 2020; Benin et al. 2020; Nalini, Selvaraj, and Kumar 2020).The research aims to enhance Voltage Profile in areas where electrical networks are inadequate or where sensitive loads must be safeguarded against issues like low power factor, voltage profile, and reactive power compensation. In a Grid-Connected based Wind Energy Conversion System system, ivoltage profile techniques such as STATCOM and SVC are used.

## MATERIALS AND METHODS

This project was completed in the Saveetha School of Engineering's Power Electronics Lab. 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, for a total of 14 samples tests has been carried out (g power setting parameters: Statistical test difference between means, α-0.05, Voltage Flicker-0.32%, effect size-1.4142136, mean STATCOM-0.305, mean SVC-0.2386, sd-0.0069) (Lahaçani, Aouzellag, and Mendil 2010).

### Wind Energy Conversion System (WECS)

The wind-to-electricity conversion process relies heavily on WECS. Consider a wind turbine that serves as a voltage source in an environment where reliable operation necessitates a large amount of energy storage. For optimal power production of the Voltage Profile, Wind Energy Conversion System, which is controller-based and thus grid-tied, requires efficient power converters and controllers (Jovcic 2019). To reduce pollution, the supply of Green energy as a subset of renewable energy has steadily expanded. For a cost-effective topology that uses permanent magnets for excitation instead of coils, a reliable, low-cost, and efficient generator, such as a permanent magnet synchronous generator, can be employed.

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**Static Synchronous Compensator (STATCOM)**

It is a reactive current source linked to the power grid in parallel (Tien et al. 2020; Truong, Ngo, and Thi 2017). Its reactive current may be dynamically controlled, and it compensates for reactive power in the system instantaneously (Pati et al. 2015). Flickers interfering with parallel capacitor bank switching is no longer an issue. It can, on the other hand, minimize harmonics and improve the Voltage Profile to satisfy customer expectations. Feedback time, grid voltage stabilization, system voltage loss and flicker reduction, improved transmission capability and transient voltage range are some of the areas that outperform STATCOM and surpass the competition. It also has the advantage of being smaller. It has been utilized in coal mines, wind Power systems, metallurgy, electrified railways, and urban and rural energy distribution (Krishna, Aswathi Krishna, and Sindhu 2016).

**Static Var Compensator (SVC)**

On the voltage profile and the voltage gain from the induction generator in a wind farm, SVC is coupled to WECS (Ramdan, Mulyadi, and Hasbullah 2016). Also, a dynamic reactive power compensation employing a Static Var Compensator at the point of coupling of the wind frame is unable to prevent voltage collapse, although static compensation (Fixed Capacitor Bank) is. Furthermore, the performance of the system with AI-based controllers is improved under various operating situations. SVC's application in the Wind frame is considered to be green energy, Integration is displayed using a MATLAB Simulink-based simulator. It also investigates the WECS performance advantages gained with the Harmony Search algorithm-tuned PI controller over the standard control approach.

**Statistical Analysis**

SPSS software was used to do statistical analysis on STATCOM and SVC networks. The independent factors are frequency and voltage flicker reduction, while the dependent variable is Voltage Profile. To estimate the gain, analysis tests are carried out.

## RESULTS

The Voltage profile improvement is better using STATCOM (0.33%) than SVC (0.23%). STATCOM controller-based WECS has minimal voltage profile improvement compared to SVC because it has better accuracy even for nonlinear systems.

The result provided in the Table 1 shows STATCOM controller-based Grid-connected Wind Energy Conversion System has high voltage profile improvement compared to SVC controller-based WECS as mentioned for different sample times at wind speeds of 12m / s.

Table 2 shows t-test comparisons of the STATCOM and SVC controllers for various sampling times. STATCOM has a mean value of 0.3050 which is high and the SVC has a low mean value. 0.2386 The standard deviation of both controllers is 0.01607 STATCOM and 0.0069 SVC.

Table 3 displays independent samples t-tests for the two algorithms and observed significant differences in power. Based on the independent T test the significance value is 0.041 ($p < 0.05$) statistically significant within the limit of study.

Figure 1 and Figure 2 show the simulation outputs for STATCOM and SVC-based WECS. Figure 3 represents a comparison bar chart of the voltage profile techniques estimating that the STATCOM algorithm provides less voltage flicker than the SVC algorithm. It is seen from Table 1 that STATCOM controller-based WECS have minimal voltage profile improvement as compared to SVC controller-based WECS. Values are noted for different sampling times under a wind speed of 12m/s.

## DISCUSSION

The voltage profile techniques such as STATCOM and SVC controllers have been implemented in Grid-connected based Wind Energy Conversion System and voltage profile analysis has been done. From the obtained results it is inferred that STATCOM controller-based WECS has a lower Voltage Flicker than Static Var Compensator SVC. By analyzing the High Voltage Flicker of the wind energy conversion system using SVC and STATCOM, the High Voltage Flicker of the Innovative Static Synchronous Compensator was lower than that of SVC. So the improvement in Voltage Profile is better by using STATCOM, where it is better to upgrade the innovative voltage profile reduction technique using STATCOM 0.33% than SVC 0.23%.

SVCs and STATCOMs are used in (Rahman and Tiwari 2016) to enhance the voltage stability of the electrical network. The synchronization of the voltage compensating mechanisms enhances the system's performance and reliability. To get satisfactory results, linear control systems employ PI controllers that are adjusted for optimum operating conditions. The disadvantage of such PI controllers is as the operating parameters of the system change, their effectiveness declines. Nonlinear controllers can therefore deliver. A high level of control is above a broad range of working circumstances (Tien et al. 2020). They may modify the controller parameters to account for the volatility of wind farms. Green energy provides the highest environmental benefit and includes solar, wind power is the fastest-growing renewable energy technology (Krishna, Aswathi Krishna, and Sindhu 2016). By the end of 2022, wind power is expected to account for 12% of total global energy demand. With the explosive growth of wind farms that produce green energy effective implementation, it's important to transport generated power to the grid via a transmission system. It is common knowledge that series compensation is an efficient way to increase the energy transfer capacity of a conventional distribution grid. Sub-synchronous resonance could be a concern in voltage stability networks fed by steam turbine driven synchronous generators “Third Supplement to a Bibliography for the Study of Subsynchronous Resonance between Rotating Machines and Power Systems” 1991, ((Yenealem et al. 2020).

The limitation of this research focus on it’s obvious that as the number of turbines grows, so does reactive power consumption, and as a consequence, voltage lowers (Diedrichs, Beekmann, and Kruse 2012). Voltage deviations caused by the addition of these generators can dramatically reduce the amount of power these generators can supply to the transmission network(Hameed and Garg 2014). As a continuous reactive power compensation device, shunt flexible alternating current transmission system devices controllers are used to improve voltage profile (Zobaa, Aleem, and Balci 2018; Suliman 2020). The Innovative Static Synchronous Compensator is connected to the storage system to solve the voltage quality. concerns (Ramdan, Mulyadi, and Hasbullah 2016). When the system is connected to non-linear or sensitive loads, harmonics and other unnecessary components are reduced (Swetha and Polayya, n.d.; Ray et al. 2017). Because STATCOM was referenced by the majority of authors in the literature, it is the preferred technique for enhancing voltage profile in wind energy conversion systems.Finally, the work will deliver some recommended control strategies to enhance the stability performance of future power systems and suggest insight topics for further work.

## CONCLUSION

The Voltage Profile Enhancement in Grid-connected based Wind Energy Conversion System employing STATCOM is superior to SVC, according to the findings. Grid-connected Wind Energy conversion systems using STATCOM are better than SVC. A system using a voltage profile technique such as STATCOM modulation provides 0.33% compared with the SVC modulation provides 0.23%. Based on the independent T test the significance value is 0.041 ($p < 0.05$) statistically significant within the limit of study.

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## 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 Voltage Profile in Grid-tied WECS using SVC and STATCOM controller

| **Inductive reactive power (W)** | **Voltage Flicker in (Volts)** | |
|---|---|---|
| | **SVC** | **STATCOM** |
| 3000 | 0.23 | 0.33 |
| 3200 | 0.24 | 0.3 |
| 3400 | 0.24 | 0.32 |
| 3600 | 0.25 | 0.31 |
| 3800 | 0.23 | 0.3 |
| 4000 | 0.24 | 0.29 |
| 4200 | 0.24 | 0.29 |

Table 2. The standard and suggested methods are compared using a T-test with the reactive power range from 3000 to 4200. The mean voltage profile value of the recommended method is 0.2386, which is lower than the mean value of 0.305 for ordinary systems.

| **Group Statistics** | | | | | |
|---|---|---|---|---|---|
| | **GROUP NAME** | **N** | **Mean** | **Standard Deviation** | **Standard Error Mean** |

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| | | | | | |
|---|---|---|---|---|---|
| Voltage Flicker | SVC | 7 | 0.2386 | 0.0069 | 0.00261 |
| | STATCOM | 7 | 0.305 | 0.01607 | 0.00607 |

Table 3. The independent sample test revealed a substantial variation in voltage magnitude and fluctuations among the STATCOM and SVC. Since the value of significance is 0.041 ($p < 0.05$) which is considered to be statistically significant.

| **Independent Samples 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 Difference | 95% Confidence Interval of the | |
| Voltage Flicker | Equal variances assumed | 5.21 | 0.041 | -10.048 | 12 | 0 | -0.06643 | 0.00661 | -0.08083 | -0.05202 |
| | Equal variances not assumed | | | -10.048 | 8.139 | 0 | -0.06643 | 0.00661 | -0.08163 | -0.05123 |

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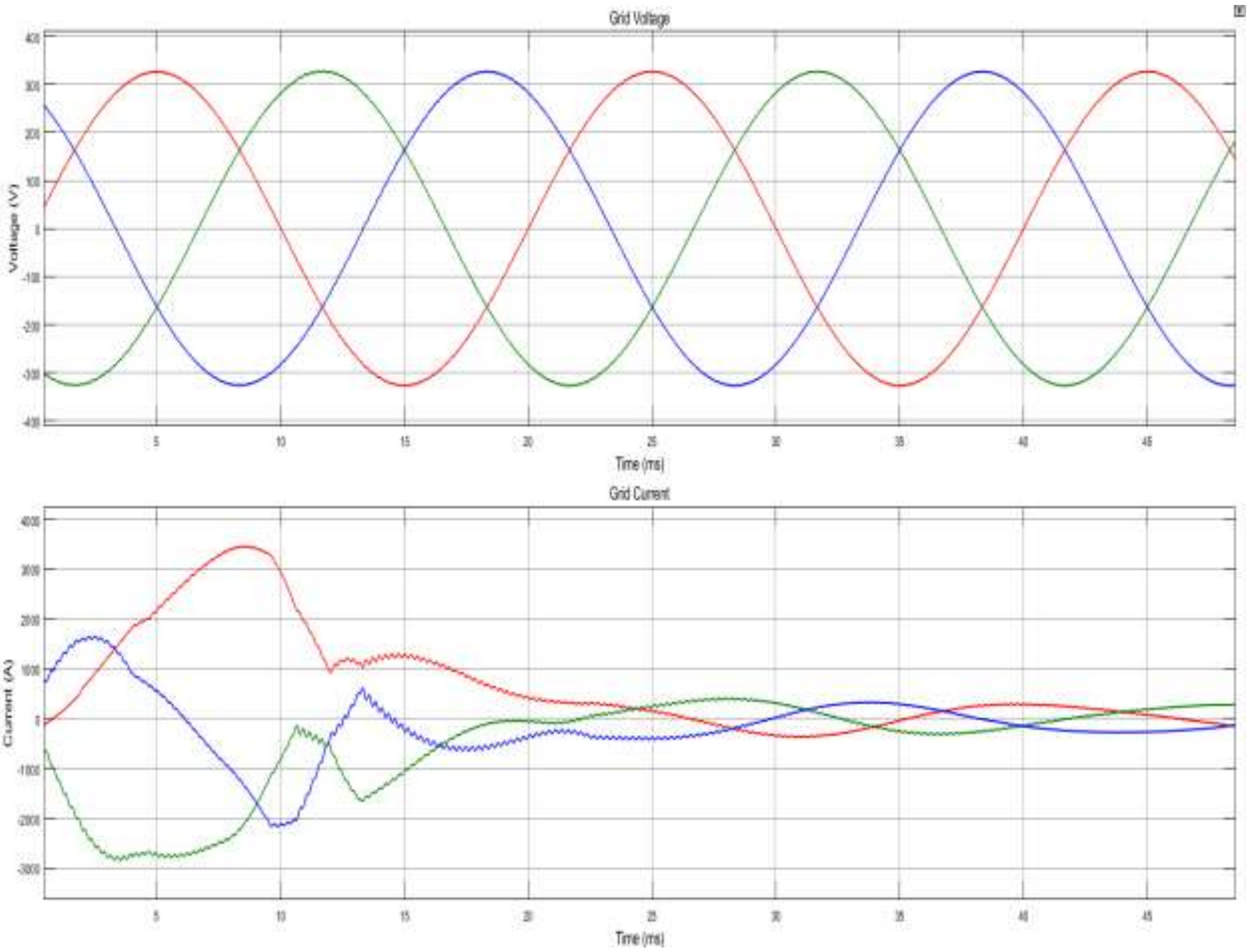


Fig. 1. High Voltage Flicker 0.31% curve for STATCOM controller-based grid-tied WECS.X-axis represents improved Grid voltage and current of STATCOM. Y-axis represents time in seconds (S)

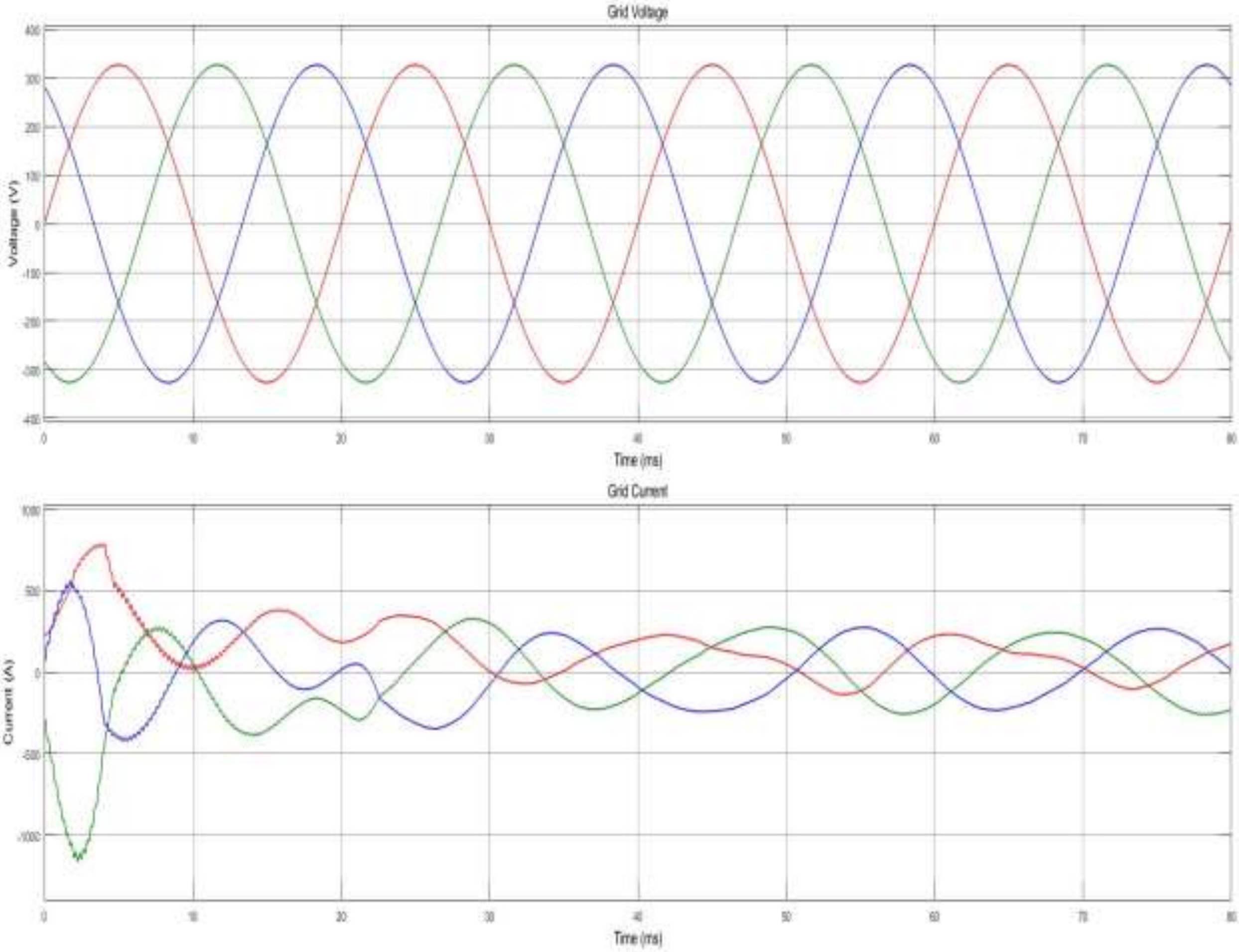


Fig. 2. High Voltage Flicker 0.23% curve for SVC controller-based grid-tied WECS.X-axis represents improved Grid voltage and current of SVC. Y-axis represents time in seconds (S)

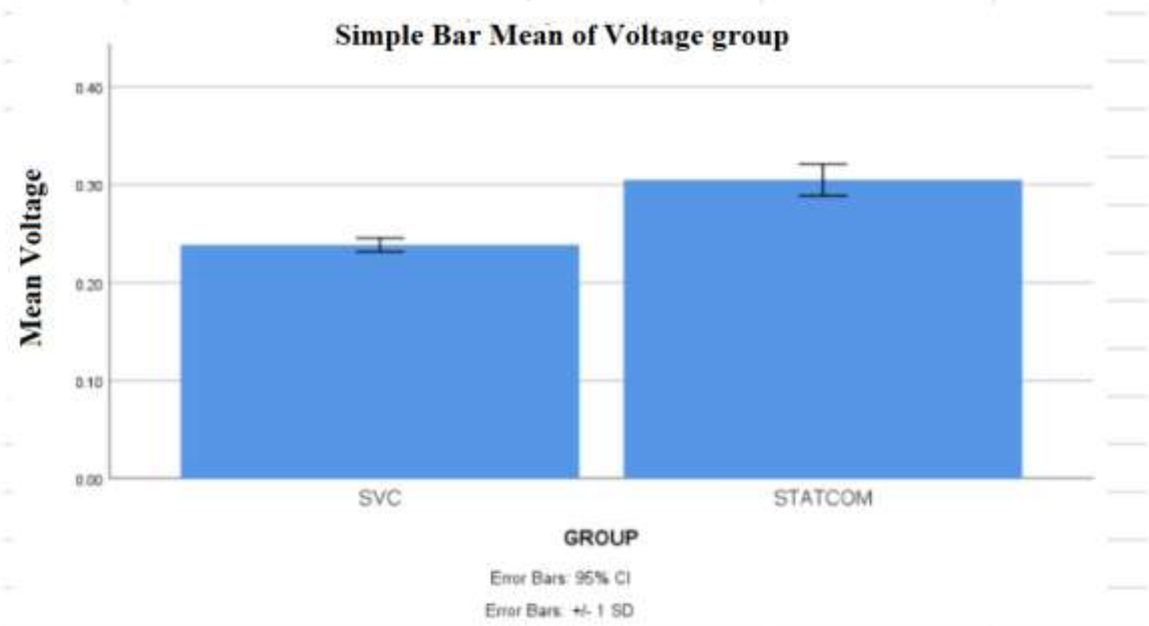


Fig. 3. Comparison of STATCOM and SVC controllers in terms of mean Voltage Flicker. The mean Voltage Flicker of STATCOM is less than the SVC controller and the standard deviation of STATCOM is more than SVC. X-Axis: SVC Vs STATCOM controller Y-Axis: Mean Voltage Flicker ± 1 SD.