VOLTAGE INSTABILITY MITIGATION IN THE HYBRID SYSTEM USING FACTS DEVICE

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Abstract: The demand of Power is increasing day by day. To fulfill the demand for power, renewable resources which are Eco friendly are alternative. Solar and wind power systems being the most environment-friendly renewable energy resources are getting a lot of attention to meet the demand for power. But as these resources are fluctuating and are dependent on atmospheric conditions, system stability may get affected. The Power Quality issues like voltage instability and harmonics are the main problem when generating power through solar and wind systems. These kinds of issues must be mitigated while implementing these eco-friendly renewable energy resources. The simulation model for solar and wind power systems has been presented in this research paper. To mitigate the issues of voltage instability and harmonics FACTs device as a controller is implemented. The simulation is done by using ETAP software.

Keywords: Solar and wind module, Flexible AC Transmission devices (FACTs), Electrical Transient Analyzer Program (ETAP) software, Proportional Integral (PI), Maximum Power Point Tracking (MPPT).

1. Introduction :

To meet the country's energy demand, India is currently reliant on a traditional source of energy. A Natural state is quickly disappearing due to its limited size [1]. Besides that, there are several disadvantages to relying on traditional fossil fuels. As per the latest reports, the world's largest economy is continuously increasing, and electricity generation is expected to rise in the future [2]. The most significant disadvantage of using traditional energy sources to meet demand is that it they are dangerous for the environment and unsustainable. Traditional pollution contributes to global warming, skin cancer,-and other problems [3].

As a result, a source is required which must be environmentally friendly and capable of meeting the nation's energy demands. Renewable energy resources are currently the only alternative that can meet this condition, making them an excellent replacement for conventional energy [4]. The only problem with renewable energy resources is that they are fluctuating in nature and due to this there are power quality issues when the power generated from these resources is connected to the grid. For the last many years, various technologies are employed to improve power quality in the electric power grid. FACTS devices are used in power systems to improve power quality issues and to increase the power efficiency of the system [5]. It employs various controllers to monitor the poor power quality in the utility system. To regulate the quality of power in the electrical power network, different types of FACTS devices are used [6]. FACTS unit that can transmit high voltage to the transmission system network can also provide reactive power quickly [7]. A static var compensator is a FACTS device that regulates voltage, power factor, and voltage control in a network system. SVC stands for Static Var Compensator VC is made up of a thyristor powered or switched reactor, as well as a thyristor, switched capacitor, or a mixture of the two.The multilevel 11- level inverter was used to reduce harmonics and cost of the inverter. Solar Photovoltaic panels were linked to an inverter in parallel or series. A simulation was done by using MATLAB software and the hardware model had also been done. The simulation results showed a reduction in voltage harmonics [10]. The power quality of wind and solar power plants was improved by using standard

IEEE. By using these IEEE standard harmonics and voltage flicker was changed and IEC std was used for improvement [12]. In this research, the simulation model for such a combination of solar PV and wind systems had completed. The power quality was improved in the solar PV system or wind system by using D- STATCOM. Total harmonic distortion THD was reduced with a limit of 5% in the solar PV or wind system and the simulated results were shown by using MATLAB software [13]. The simulated model of the PV system was implemented. The fluctuation had improved in the PV system due to weather changes. Total Harmonic Distortion and the effects in the PV system were reduced. The simulated result for two conditions i.e before the PV system due to weather change and then after the change in the PV system. THD currents were also shown in the waveform of the simulated graph [14]. A simulated model of a PV system was linked with the grid, and the conversion was handled by a cascaded H-bridge inverter. MATLAB software was used for simulating the model. Zeta converters were used for converting DC to DC and it is also connected to the MPPT (Maximum Power Point Tracker) for utilization [15]. The notch filter was used in this research to improve power efficiency. Harmonic distortion was minimized, and the single-phase grid was connected using PCC. MPPT (Maximum Power Point Tracking) systems were also linked to PV solar power systems. The power production of PV or wind power generation was improved in this article and tests various current variations, solar isolation, and changing wind speed [16].

The proposed work involves an off-grid PV device with a battery. The PV generator with the attached load uses the battery bank. For power quality in the framework, the FLC (Fuzzy Logic Controller) and P&O algorithm were also used. For the simulation model, MATLAB software was used. In the system, variable constant irradiance and temperature were shown in the form of graphs [18]. The harmonic technique-based model FFHD (Flexible Extended Harmonic Domain) was used in the standalone PV system in this research work and this research showed how to run renewable rechargeable batteries freestanding network that provides optimum power to nonlinear loads. MATLAB software was used to simulate the model [19].

2. Hybrid Energy:

Hybrid energy systems are coming up with the potential of providing a sustainable energy system thatcan overcome the future energy demand and due to this reason, they are becoming more popular as photovoltaic solar power systems that can provide electricity that is carbon-free sustainable, and advance in terms of energy technology [8]. When we say interns of hybrid energy, that means anythingthat consists of two or more renewable sources of energy sources that are used together to provide improved device efficiency and greater energy supply balance. The Block diagram of the Hybrid system consists of Solar and Wind with an inverter to convert DC supply into AC supply is shown in Figure 1.

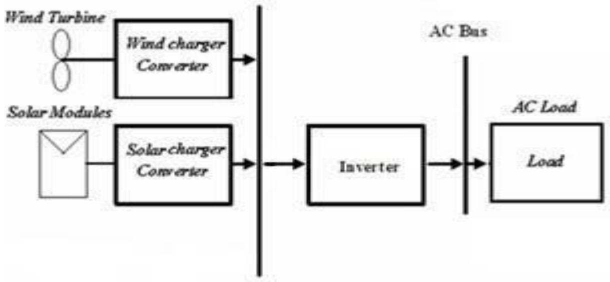

Figure 1 Simulink model of Solar PV

The hybrid renewable energy sources systems were integrated into a grid system in this study. To enhance the quality of electricity PI controllers were used and simulations were also done. A fuzzy

controller was also used for comparing the result with the PI controller. By using an inverter power
quality of hybrid solar or wind was also solved and a shunt active filter was also used [11]. The total energy of hybrid solar power was improved by using various ways. The voltage stability was transmitted to the load system by wind generation, and power quality was mitigated in solar power systems with the aid of an APQC compensator [17]. Simulation work had done and the model of solar or wind energy was connected and both were mitigated by using MG techniques. As a result of the large number of them deployed at customer sites, they are becoming increasingly appealing to customers. In this work, both wind and solar renewable energy were present [20].

3. Power Quality:

The phrase "power quality" relates to electrical quality. When the voltage in the system is low, frequency and sinusoidal waveform are all smooth. When the mechanism does not shift, this is referred to as power efficiency. Many power quality issues exist in the power system, including low power factor, electrical harmonics, voltage instability, and equipment reliability.

Parameters of Power Quality:

1 Continuity of service – When the voltage system is dropped in the continuity of power system service.
2 Variation in voltage magnitude – When the voltage magnitude changes and exceeds the normal voltage range, the voltage variance changes spontaneously in the device
3 Transient voltages and currents – When there is a sudden shift in the sinusoidal waveform, the transient voltage and current are abnormal.

Power Quality Problems:

Many difficulties arise with power quality and in return affect the electrical network's power. These Problems with the power system networks are almost unavoidable. Due to this, to preserve the quality of electricity, appropriate equipment must be held in place to avoid the effect of these issues.

Different power quality problems are as follows:

1. Voltage sag or dip.
2. Interruptions that are only a few seconds long
3. Prolonged pauses
4. A surge in voltage
5. The voltage rises
6. Distortion of the harmonic spectrum
7. Changes in voltage
8. Noise Unbalanced voltage

1. Voltage sag: - It is described as when a short circuit or overload condition is present in RMS voltage during a short period of time. When the Reactive power falls around 10 percentage points and 90 percent of a total voltage level for half a minute this is known as a voltage sag as shown in Figure 2.

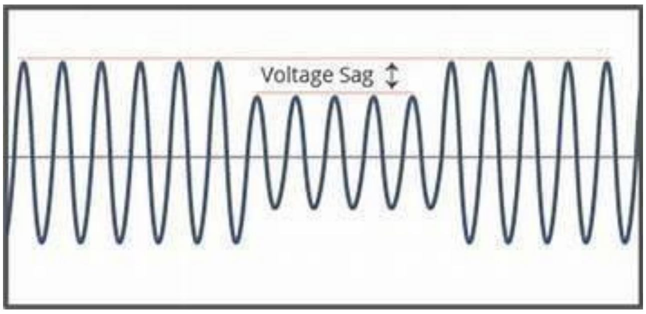

Figure. 2: Voltage sag

2. **Very short interruptions:** -Very short interruption is defined as the nominal voltage level being reduced by 10% when the voltage supply level is reduced as shown in Figure 3. The period times of short interruption is 0.5 to 3second.

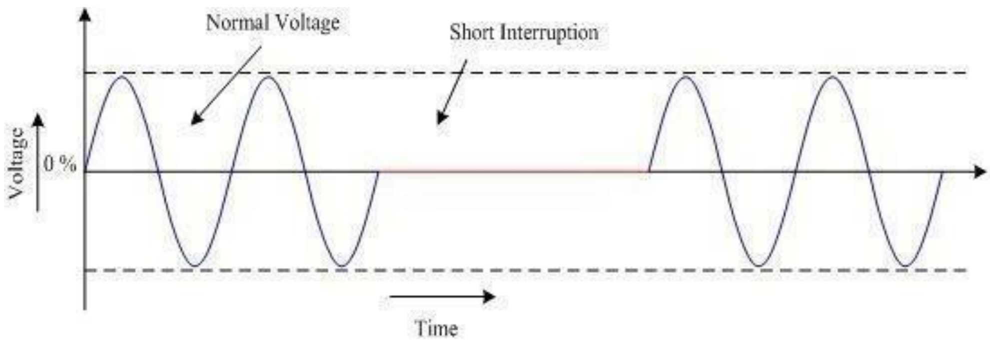

Figure 3: Voltage sag

3. **Long interruptions**: - Long interruption is defined as the total electrical supply interruption lastingmore than 1 to 2 seconds as shown in Figure 4. It is caused by human error, equipment failure, overheating, and other factors.

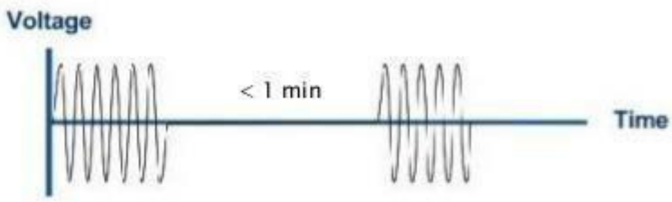

Figure 4.: Voltage Spike

4. **Voltage Spike:** - Variation in voltage value over timescales ranging from a few microseconds to a few milliseconds as shown in Figure 5. Even at low voltage, these variations can exceed thousands ofvolts. It is caused by lightning, a low power factor, heavy loads, and electromagnetic system interference.

Industrial Engineering Journal
ISSN: 0970-2555
Volume: 52, Issue 4, No. 3, May 2023

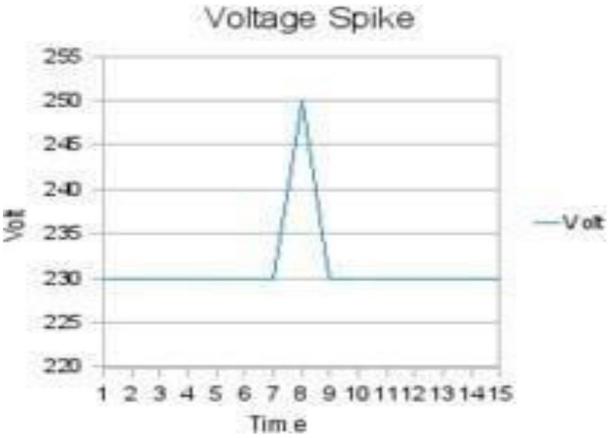

Figure 5.: Voltage Spike

5. **Voltage Swell:** - Voltage swell is opposite to the voltage sag. When the short circuit, overload is produced in RMS voltage for a long p as shown in Figure 6. When the Reactive power falls from 10%and 90% of both the maximum voltage range with more than a few-cycle time with less than a few minutes, it is called a voltage swell. It is caused by lightning flashes, faulty machinery, and damaged transformers, among other things.

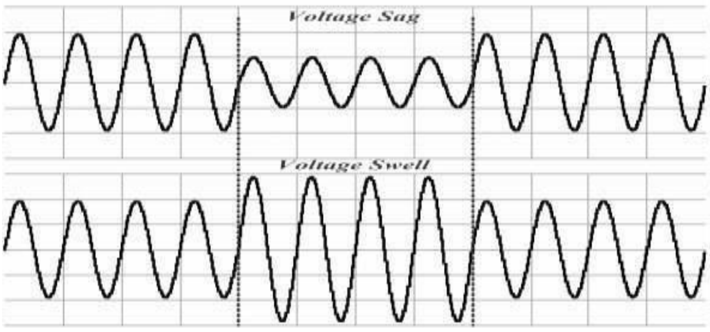

Figure 6: Voltage Swell

6. **Harmonic Distortion:** IEEE defines harmonics as continuous voltages or currents with frequenciesthat are constant integer multiples of the power system. For a 60-Hz arrangement, this means the fundamental vibrations are 120,180 Hz (2nd and 3rd harmonics), and so on. Simply defined, harmonics distortion happens when a sinusoidal waveform is changed into a non-sinusoidal structure, causing a change in the problem's power quality [23]. The non-sinusoidal shape is created by combining sine waves with differing levels and switching frequency and energies which are different combinations ofthe device rate as shown in Figure 7.

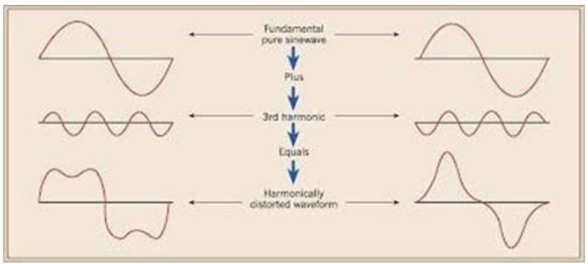

Figure 7.: Harmonic distortion

Industrial Engineering Journal
ISSN: 0970-2555
Volume: 52, Issue 4, No. 3, May 2023

7. **Voltage fluctuation:** - As the voltage in the device fluctuates and the voltage value oscillates, the modulated amplitude-frequency period ranges from 0 to 30 Hz as shown in Figure 8. It is the source ofheavy loads, arc burn, and the inability to start a large motor.

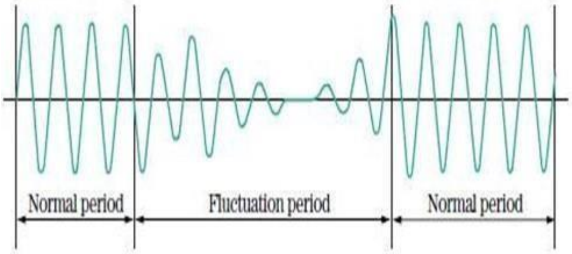

Figure 8: Voltage fluctuation

Harmonics:

Harmonic is a distortion in the current and voltage waveforms in the device. Non-linear loads in the system, such as the rectifier, inductor, and magnetic devices, generate harmonics. The frequency rangeof current harmonics AC in the power system ranges from 50 Hz to 60 Hz. Based on the type of demand utilized in the power system and the type of interaction with other power system components, the distortion waveform in current harmonics might be complicated. In most cases, voltage distortion is caused by current distortion, and all of this occurs as a result of the source impedance.

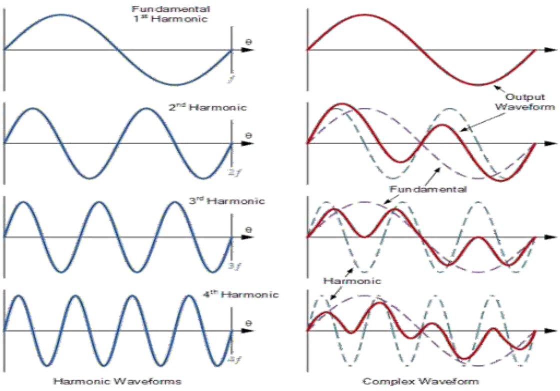

Figure 9: Harmonics waveforms and complex waveforms

Total Harmonic Distortion: It is a frequently used metric for determining the number of harmonics present in a system. The system's THD is influenced by both harmonics' current and voltage. It's also known as the harmonic ratio, which is the measure of the amount value of harmonics at the frequency components to the total value of harmonics at the frequency components.

$$TDH_V = \frac{\sqrt{V_2^2+V_3^2+V_4^2+\dots+V_n^2}}{V_1} \cdot 100\% = \frac{\sqrt{\sum_{k=2}^{n} V_k^2}}{V_1} \cdot 100\% \quad \dots\dots\dots\dots\dots\dots\dots\dots(1)$$

$\sqrt{I2+I2+I2+\dots+I2}$ $\sqrt{\sum^{n} I2}$

$$TDH_I = \frac{\sqrt{I_2^2 + I_3^2 + I_4^2 + \dots + I_n^2}}{I_1} \cdot 100\% = \frac{\sqrt{\sum_k I_k^2}}{I_1} \cdot 100\% \quad \text{..........................(2)}$$

Industrial Engineering Journal
ISSN: 0970-2555
Volume: 52, Issue 4, No. 3, May 2023

4. Simulation Model and Results

The Simulink model for hybrid i.e., solar and wind power systems is shown in Fig. 3. Five energies such as wind, solar, hydro, etc. are connected to one network with a grid. Voltage is stabilized on eachbus which is coming to be near marginal value of (95 %), and the load flow of the model is performedas shown in Figure 10 to see the voltage status of each bus and line.

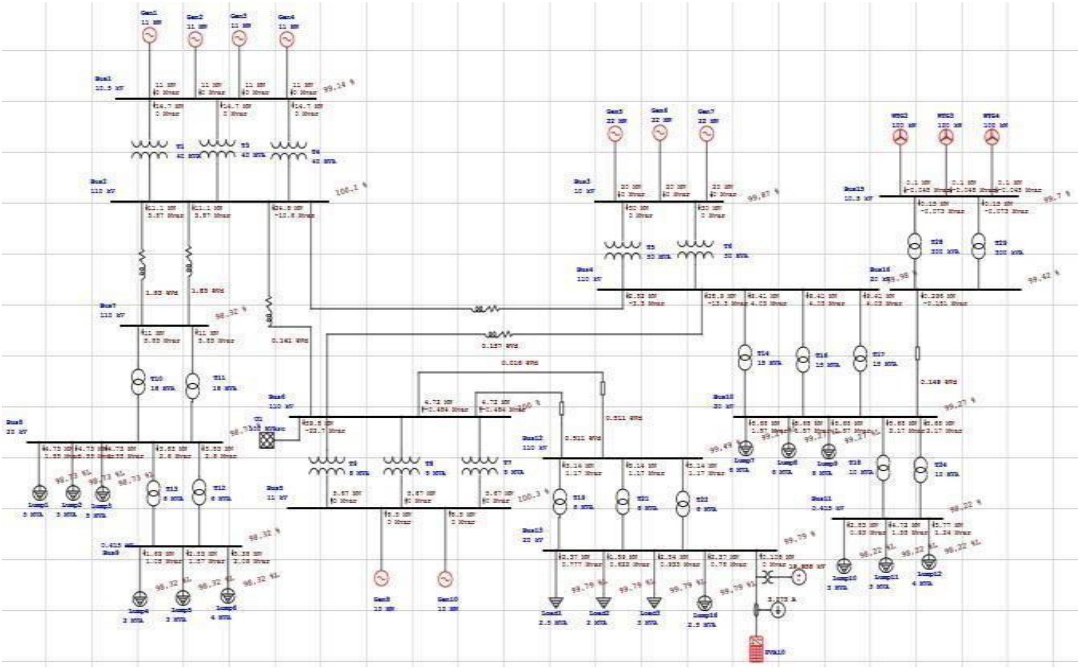

Figure 10: Load flow diagram of the Network

The given load flow diagram has a total of 15 buses. Fig. no. 3, in the load flow diagram from input data we can observe that the voltage from bus 1 to bus 15 is under voltage when no FACTS devices areused. This operating voltage at each bus is shown in Table. 1.

Table 1. Voltage percentage before using FACTs devices

BUS ID	TYPE	Condition	% Operating
BUS 8	BUS	Under Voltage	94.71
BUS 9	BUS	Under Voltage	91.12
BUS 12	BUS	Under Voltage	93.76
BUS 13	BUS	Under Voltage	94.39
BUS 10	BUS	Under	93.3

Industrial Engineering Journal
ISSN: 0970-2555
Volume: 52, Issue 4, No. 3, May 2023

		Voltage	
BUS 11	BUS	Under Voltage	94.2

Bus no. 1, bus no. 3, and bus no. 5 are the generation buses for voltage control (Figure 11). Bus no.6 istreated as a swing or slack bus. The maximum and minimum reactive power limits are also mentionedon bus 1, bus 3, and bus 5. Bus no. 13 and bus no. 15 are the reactive power and power factor control buses. The initial voltages, active power, reactive power, load angle, and power factor are also mentioned on each bus.

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Bus			Initial Voltage		Load							
					Constant kVA		Constant Z		Constant I		Generic	
ID	kV	Sub-sys	% Mag.	Ang.	MW	Mvar	MW	Mvar	MW	Mvar	MW	Mvar
Bus1	10.500	1	100.0	0.0								
Bus2	110.000	1	100.0	0.0								
Bus3	10.000	1	100.0	0.0								
Bus4	110.000	1	100.0	0.0								
Bus5	11.000	1	100.0	0.0								
Bus6	110.000	1	100.0	0.0								
Bus7	110.000	1	100.0	0.0								
Bus8	20.000	1	100.0	0.0	11.400	3.747	2.850	-7.063				
Bus9	0.415	1	100.0	0.0	6.120	3.793	1.530	0.948				
Bus10	20.000	1	100.0	0.0	13.680	4.496	3.420	1.124				
Bus11	0.415	1	100.0	0.0	9.120	2.998	2.280	0.749				
Bus12	110.000	1	100.0	0.0			0.000	-4.000				
Bus13	20.000	1	100.0	0.0	13.600	8.429	12.900	5.230				
Bus15	10.500	1	100.0	0.0								
Bus16	20.000	1	100.0	0.0			0.000	-2.000				
Total Number of Buses: 15					53.970	23.462	22.980	-5.017	0.000	0.000	0.000	0.000

Generation Bus				Voltage		Generation			Mvar Limits	
ID	kV	Type	Sub-sys	% Mag.	Angle	MW	Mvar	% PF	Max	Min
Bus1	10.500	Voltage Control	1	100.0	0.0	44.000			1.550	1.550
Bus3	10.000	Voltage Control	1	100.0	0.0	60.000			1.700	1.700
Bus5	11.000	Voltage Control	1	100.0	0.0	19.000			1.600	1.600
Bus6	110.000	Swing	1	100.0	0.0					
Bus13	20.000	Mvar/PF Control	1	100.0	0.0	0.106	0.000	100.0		
Bus15	10.500	Mvar/PF Control	1	100.0	0.0	0.300	-0.145	-90.0		
						123.406	-0.145			

Figure 11: Bus Input Data

Figure 12 shows the generation of electric power at different buses with various excitation conditionsof the generator. At Gen 10 and Gen 8 due to overload condition operating voltage is about 95% whichshows instability in system voltage.

Device ID	Type	Condition	Rating/Limit	Unit	Operating	% Operating	Phase Type
Gen5	Generator	Under Excited	0.500	Mvar	0.500	0.0	3-Phase
Gen6	Generator	Over Excited	0.600	Mvar	0.60	100.0	3-Phase
Gen6	Generator	Under Excited	0.600	Mvar	0.60	0.0	3-Phase
Gen7	Generator	Over Excited	0.600	Mvar	0.60	100.0	3-Phase
Gen7	Generator	Under Excited	0.600	Mvar	0.60	0.0	3-Phase
Gen8	Generator	Over Excited	0.900	Mvar	0.90	100.0	3-Phase
Gen8	Generator	Under Excited	0.900	Mvar	0.90	0.0	3-Phase
PVA10	PV Array	Overload	3.014	Amp	3.11	103.1	3-Phase
WTG2	Wind Turbine Generator	Overload	0.100	MW	0.10	100.0	3-Phase
WTG2	Wind Turbine Generator	Under Excited	0.000	Mvar	-0.05	0.0	3-Phase
WTG3	Wind Turbine Generator	Overload	0.100	MW	0.10	100.0	3-Phase
WTG3	Wind Turbine Generator	Under Excited	0.000	Mvar	-0.05	0.0	3-Phase
WTG4	Wind Turbine Generator	Overload	0.100	MW	0.10	100.0	3-Phase
WTG4	Wind Turbine Generator	Under Excited	0.000	Mvar	-0.05	0.0	3-Phase

Marginal Report

Device ID	Type	Condition	Rating/Limit	Unit	Operating	% Operating	Phase Type
Gen10	Generator	Overload	10.000	MW	9.500	95.0	3-Phase
Gen8	Generator	Overload	10.000	MW	9.50	95.0	3-Phase

Figure 12: Critical Report

The Operating voltage in percentage without using the FACTS device i.e., voltage instability at bus no.8 to bus no. 13 is shown in Figure 13.

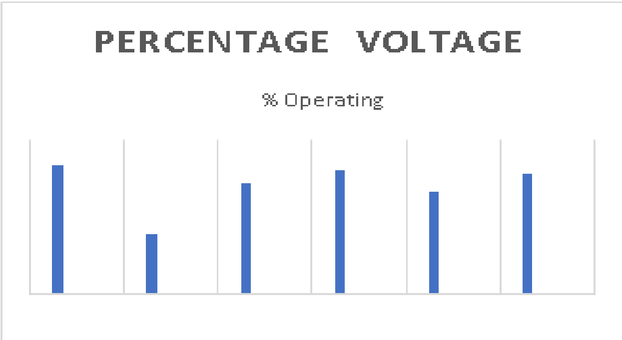

Figure 13: Graph of Voltage Instability

In Table. 2 voltage percentage after implementing the FACTS device is shown. It can be observed now that the operation percentage of voltage at different buses has been improved after implementing the FACTs Device.

Table 2. Voltage Percentage using FACTs devices

BUS ID	TYPE	Condition	% Operating
BUS 8	BUS	Normal	99.14
BUS 9	BUS	Normal	98.75
BUS 12	BUS	Normal	98.05
BUS 13	BUS	Normal	98.73

BUS 10	BUS	Normal	98.54
BUS 11	BUS	Normal	98.05

The mitigation of voltage instability using the FACTS devices is shown in Figure 14. The operating voltage is improved at bus no. 8 to bus. no.13

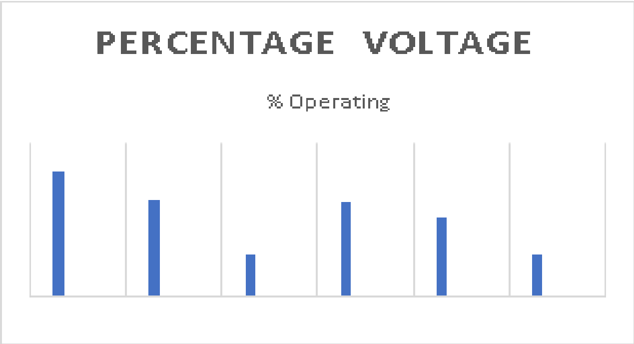

Figure 14: Graph of Voltage Stability using FACTs device

5. Comparative Analysis:

Figure 15. Shows the values of voltage at bus no. 8 to bus no. 13 without FACTS devices and with FACTS devices. The comparison clearly shows that after implementing the FACTS device in the system, the voltage instability at each bus mentioned has been improved as compared to the system running without FACTS devices.

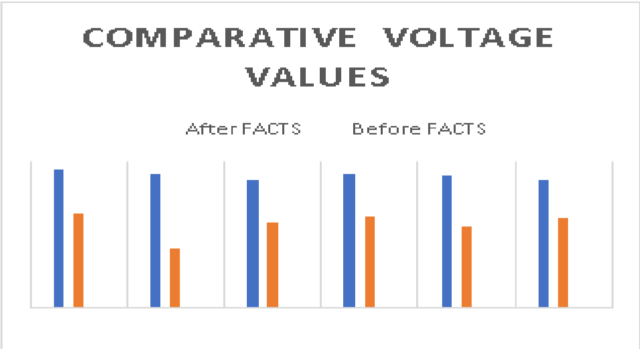

Figure 15: Comparison of voltage After FACTS and Before FACTS

6. Conclusion:

In this paper, voltage stability in the solar or wind system has been studied. Results show that voltagebecomes stable after implementing the FACTS devices. Simulation is done by using ETAP software. Results are also shown in graphical form. The Static Var compensator is used in the kind of FACTSdevices to reduce voltage stability and remove voltage surges in the system. Voltage is stabilized usingFACTS devices, and voltage is on the marginal limit at each bus.

REFERENCES:

[1] A. Zade, B. Akshay, "Hybrid solar and wind power generation with grid interconnection system for improving power quality." In Proc. 1st International Conference on Power Electronics, Intelligent Control and Energy Systems (ICPEICES). IEEE, 2016.

[2] V. Narayanan, K. Seema, and S. Bhim, "Standalone PV-BES-DG based microgrid with power quality improvements." In Proc. International Conference on Environment and Electrical

Engineering and 2019 IEEE Industrial and Commercial Power Systems Europe (EEEIC/I&CPS Europe). IEEE, 2019.
[3] C. Nagaraj, and K. Manjunatha Sharma. "Integration of hybrid solar- wind energy sources with utility grid for improving power quality." In Proc. 3rd International Conference on Recent Trends in Electronics, Information & Communication Technology (RTEICT). IEEE, 2018.
[4] V. Helać, and H.Selma, "Modeling and the impact on power quality of hybrid solar-wind power plants." In Proc. 6th International Youth Conference on Energy (IYCE). IEEE, 2017.
[5] V.N. Jayasankar, and U. Vinatha, “Implementation of adaptive fuzzy controller in a grid-connected wind-solar hybrid energy system with power quality improvement features,” Journal of Power and Energy Systems, vol. 21, no. 6, pp. 1-5, Aug. 2020.
[6] T.N. Gupta, S. Murshid, and B. Singh, “Power quality improvement of single-phase grid-connected hybrid solar PV and wind System,”. In Proc.8th Power India International Conference (PIICON), IEEE, pp. 1-6, 2019.
[7] C.M. Mukundan, and P. Jayaprakash. "Cascaded H-bridge multilevel inverter-based grid integration of solar power with PQ improvement." In Proc. International Conference on Power Electronics, Drives and Energy Systems (PEDES). IEEE, 2021.
[8] Chishti, Farheen, S. Murshid, and B. Singh. "Development of wind and solar-based AC microgrid with power quality improvement for local nonlinear load using MLMS." IEEE Transactions on Industry Applications, vol. 55, no. 6, pp. 7134-7145, 2021.
[9] V. N. Jayasanka, and U. Vinatha, “Implementation of adaptive fuzzy controller in a grid connected wind-solar hybrid energy system with power quality improvement features,” In Proc. Biennial. International Conference on Power and Energy Systems: Towards Sustainable Energy (PESTSE), IEEE, pp. 1-5, Jan, 2016.
[10] Parija, Bhagyashree, "Power quality improvement in hybrid power system using D-STATCOM," in Proc. 3rd International Conference on Computing Methodologies and Communication (ICCMC). IEEE, 2019.
[11] Wang, Zhifeng, "Assessment of wind energy and wave energy resources in Weifang sea area." International Journal of Hydrogen Energy, vol. 41, no. 35, pp. 15805-15811, 2021.
[12] N. Tripurari, M. Shadab, and B. Singh. "Power quality improvement of single-phase weak grid interfaced hybrid solar PV and wind system using double fundamental signal extractor-based control." IET Generation, Transmission & Distribution, vol.13, no. 17, pp. 3988-3998, Nov. 2020.
[13] Vargas, Uriel, "Harmonic modeling and simulation of a stand-alone photovoltaic-battery-supercapacitor hybrid system." International Journal of Electrical Power & Energy Systems, vol. 105, pp. 70-78, 2019.
[14] Rekioua, Djamila, F. Zaouche, H. Hassani, T. Rekioua, and S. Bacha. "Modeling and fuzzy logic control of a stand-alone photovoltaic system with battery storage." Turkish Journal of Electromechanics and Energy, vol. 4, no. 1, 2021.
[15] I. Hussain, B. Singh, and S. Mishra, “Optimal operation of PVDG- battery-based microgrid with power quality conditioner,” IET Ren. Pow. Gen., vol. 13, no. 3, pp. 418-426, 2019.
[16] N. Phuangpornpitak, and S. Kumar, “PV hybrid systems for rural electrifications in Thailand” Renewable and Sustainable Energy Reviews, vol. 11, no 7, pp. 1530-1543, Sept. 2018.
[17] L.A. Ribeiro, O.R.Saavedra, and S.L. de Lima, “Isolated micro-grids with renewable hybrid generation: The Case of Lençóis Island” , IEEE Transactions on Sustainable Energy, vol. 2, no.1, pp. 1-11, 2011.

[18] L. Xu ; XinboRuan ; C. Mao ; B. Zhang ; Y. Luo "An Improved optimal sizing method for Wind-Solar-Battery hybrid power system" , IEEE Transactions on Sustainable Energy , vol. 4, no. 3 , pp.774 – 785, 2021.
[19] Y.M. Atwa, E.F. El-Saadany, M.M.A. Salama, and R. Seethapathy, "Optimal renewable resources mix for distribution system energy loss minimization. Power Systems," IEEE Transactions on, vol. 25, no. 1, pp. 360 –370, Feb. 2014.
[20] W.D. Kellogg, M.H. Nehrir, G. Venkataramanan, V. Gerez,n "Generation unit sizing and cost analysis for stand-alone wind, photovoltaic, and hybrid wind/PV systems" , IEEE Transactionson Energy Conversion, vol. 13, no. 1, pp. 70-75, 2004.
[21] S.Vig, B.Singh, "Power Comparison of Single And Multiple Connected Wind Turbines", International Journal of Advance Science and Technology, vol. 29, no. 10S, May-2020.
[22] S.Vig, B.Singh, "Optimal Power Dispatch of WECS and UPFC with ACO and ANFIS Algorithms", International Journal on Electrical Engineering and Informatics, vol. 10, no. 1, March 2018.