RESEARCH ARTICLE OPEN ACCESS

Modeling and STATCOM-optimized Voltage Regulation of the Solar-Wind Hybrid Micro-Grid using GA

Chandana.K*,Swarna.S*,Spandana.K*,Yaswanth.B*,Kiran kumar.K**
**(UG scholar, Department of Electrical and electronics engineering,Sree vahini institute of science and technology,Tiruvuru.)*
***(HOD, Dept of Electrical and Electronics Engineering ,Sree Vahini Institute of Science and Technology, Tiruvuru.)*

ABSTRACT:
Weather conditions have a significant impact on the ability of wind and solar photovoltaic (PV) systems to generate electricity.Its production varies because of their sporadic nature. Thus, it is becoming more crucial than ever for energy transmission and distribution networks to provide quick correction.STATCOM can be used to compensate for reactive power and reduce voltage fluctuations brought on by the system and renewable energy sources.In this work, a Solar PV-Wind Hybrid Micro-grid is modelled, and the rise in the system's stable operational limit in the event of the inclusion of STATCOM is investigated.This paper's main contribution is the optimization of gain settings for four PI controllers in STATCOM using GA, which leads to superior responses and voltage stability given the nonlinear nature of the solar-wind hybrid micro-grid.A 0.4 MW solar PV power system model, a 2 MW wind turbine model based on a DFIG, and a STATCOM rated at 3 MVAR are among the Simulink models of the system design. Using a traditional PI controller is certified to reduce voltage fluctuation at the end of the bus bar by 8%. When PI controller results from GA-based optimization are compared to those from conventional controllers, the results are better.
Keywords **-**Static synchronous compensator, Flexible AC transmission systems, GA, PV-Wind hybrid system, Voltage control.

Date of Submission: 06-03-2023 Date of acceptance: 19-03-2023

I. INTRODUCTION

Particularly in recent years, the use of renewable energy sources has gained momentum. Research is moving towards alternative energy and distributed production due to rising energy consumption, quick technological advancements in energy production, and growing public awareness of environmental protection. For applications with modest installed capacity, a hybrid structure with an effective photovoltaic (PV) system and a wind energy system may be built utilising a variety of control systems. Reactive power compensation is an emerging requirement for stable functioning of a hybrid. system since renewable energy sources like wind alone and hybrid Wind/PV are not totally safe in satisfying the demand for the load.[1]. New FACTS topologies, however, are growing to strengthen the stability and security of micro-grids. STATCOM is a shunt-connected inverter-based device that enhances power quality in alternating current systems and is a part of the FACTS family of devices. In 1991, Japan hosted the STATCOM's first installation. It offered voltage stability with an 80 MVAR rating. Since then, real-time controllers have made it possible to develop sophisticated and complicated control algorithms.New FACTS topologies, however, are growing to strengthen the stability and security of micro-grids. STATCOM is a shunt-connected inverter-based device that enhances power quality in alternating current systems and is a part of the FACTS family of devices. In 1991, Japan hosted the STATCOM's first installation. It offered voltage stability with an 80 MVAR rating. Since then, real-time controllers have made it possible to develop sophisticated and complicated control algorithms.These devices work in energy systems to improve power factor, balance loads, control voltage, and eliminate harmonics. The requirement to construct additional channels is eliminated by expanding the transmission lines' capacity. A few control techniques are employed to enable power system functioning within the necessary operational bounds. The most often used controllers are those based on artificial neural networks (ANN), fuzzy logic controllers (FLC), proportional-integral (PI), and proportional-integral-derivative (PID) models. Commercial STATCOM devices often have ordinary PI type controllers, and the performance of STATCOM is defined by the controller's efficiency.

Thus, the present research is focused on achieving a more reliable and flexible operating of STATCOM for changes of the hybrid power system.Several STATCOM-related studies have been conducted recently. A small amount of study was done in 2010 on a hybrid PV-Wind supply system with STATCOM interface for a water-lift station and reduced voltage instability. Several studies have examined the effects of FACTS controllers on the stability of power networks coupled to doubly fed induction generators in the literature, with a special emphasis on the results of rotor angle responses.

A voltage source control (VSC)-based STATCOM control mechanism It has been recommended to use conventional and direct-current vector control approaches. None the less, they did not deal with a hybrid system; they just dealt with the voltage variation from the system.Reactive power support for voltage control in hybrid power systems powered by wind energy conversion systems has been reported.However, STATCOM was not used in the study to employ a load side converter to reduce voltage fluctuation. According, a parallel-resonance bridge type fault current limiter (PRBFCL) can improve the transient stability of a hybrid power system.as well as using this approach, voltage fluctuation has been minimized. The review of the literature reveals a paucity of studies on the STATCOM system-based voltage spikes brought on by hybrid solar-wind microgrids.

The conventional FACTS devices still need to be improved by optimising the controllers and thorough study has to be done under various operating situations as the installation of PV and wind power systems increases. The dynamic response of hybrid power systems with the best STATCOM gain setting can be seen in reference.A robust control method using SVC and an automatic voltage regulator was suggested by reference. (AVR). The genetic method is used to obtain the PI control parameters for the SVC and AVR while simultaneously addressing an optimization problem. For the isolated hybrid power system model-performance analysis of a Takagi-Sugeno fuzzy logic (SOA-TSFL) based controller, Reference was using a searcher optimization technique.By incorporating STATCOM for reactive power compensation, the study's objective is to exceed the current power system architecture's reliable working limit. Additionally, it aims to lessen voltage fluctuations brought on by the varying nature of renewable energy sources. To get a positive reaction, STATCOM automatically determines the most effective PI parameter modifications based on GA.

II.WIND POWER SYSTEM MODELLING

Nowadays, Doubly Fed Induction Generator (DFIG) is one of the most favoured wind generators [13]. The stator windings that make up DFIG are coupled to a fixed.In the rotor windings are a frequency 3-phase network and back-to-back voltage-based converters. Double-fed describes a system where the rotor voltage is induced by the power converter and the stator voltage is taken from the mains.The technology can function with a speed differential of up to 40% but only allows for huge variations in speed. By infusing electricity into the rotor at various frequencies, transducers alter the mechanical and electrical frequencies.Power converters or controllers govern the behaviour of the generator in both normal operation and fault circumstances.The DFIG is made up of a series of voltage-induced converters that are bi-directionally coupled to the rotor windings and connected directly to the fixed-frequency three-phase grid.

Two converters make up the power converter unit; an inverter on the grid side and a rectifier on the rotor side control one another. The major goal is to regulate the active and reactive powers as well as the rectifier's rotor current components. On the grid side, the inverter also regulates the DC link voltage and makes sure that the converter's operation is integrated with the power factor.DFIG offers numerous advantages such as the regulating capabilities of active and reactive power by rotor current.In Fig. 1, it features two consecutive converters for rotor side and grid side control. Grid voltage (Vbus), reactive power component (Q), and three-phase current component (Ia, Ib, and Ic) are all taken into account in the grid side control circuit of the wind, and Vbus and Id&Iq are controlled. Voltage and current components (Vd and Vq) are transformed into three-phase signals using space vector operations. PLL uses voltage values to calculate the angles, which are then employed in space vector transformation (Park and Clarke).

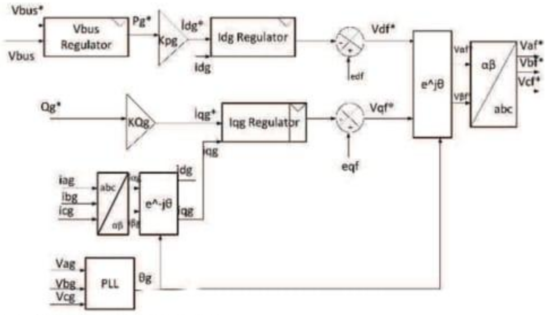


Fig. 1. Grid side control circuit.

ISSN: 2248-9622, Vol. 13, Issue 3, March 2023, pp. 61-69

The Simulink environment is used to construct the control circuit. the power of the aerodynamic model is By figuring out the mechanical torque as a function of airflow on the blades, the rotor may be driven. Wind speed (Vw) is taken into account as the typical speed on the region where the blades sweep.The wind turbine's power equation is provided in (1)

$$P_W = \frac{1}{2} C_p \rho A V_w^3$$
(1)

The aerodynamic torque is provided in (2)

$$T_t = \frac{1}{2} \rho R^3 V_w^2 C_t$$
(2)

the end velocity ratio of a wind turbine is stated in (3)

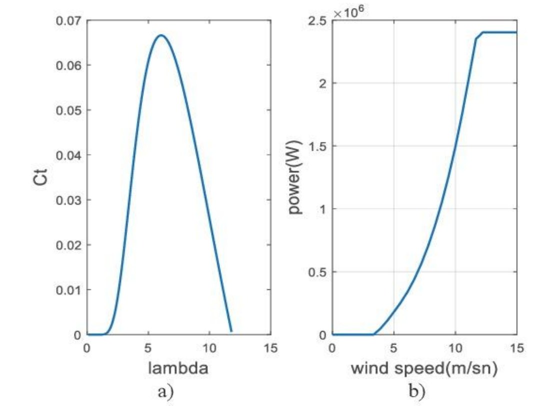
$$\partial = \mathrm{R}\ {}^{\Omega_t}/_{V_w}$$
(3)

The analytical equation for the power coefficient (Cp), where k is a constant, R is a ratio, Ct is the torque coefficient, A is the surface, r is the air density, and Wt is the angular speed of the rotor, depends on the angle of inclination () and the turbine end velocity ratio ().In (4) and (5), the power factor equation is given:

$$C_p = (k^1 \frac{k^2}{\partial_i} - k3\beta - k4\beta^{k5}k6) \qquad \frac{e^{(\frac{k7}{\partial i})}}{(\ 1})$$
(4)

$$\partial \mathrm{i} = 1/(\partial + \mathrm{k8})$$
(5)

These equations lead to the features seen in Fig. 2. The chart shows that the output power reaches 2 MW at a wind speed of 12 m/s. A wind turbine model is created using these power and torque equations, and indirect speed control is simulated to get the maximum power point. A DFIG was modelled using some accepted data for the Doubly Fed Induction Machine.



2. Characteristics of wind turbine: a) λ-Ct characteristic; b) Velo

Fig. 2.1 shows the wind turbine's characteristics: a) the -Ct characteristic; and b) the Velocity-Power (v-P) characteristics.

III. PHOTOVOLTAIC POWER SYSTEM MODELLING

Solar PV panels utilize the energy from the sun's beams to produce electricity in DC form. Many solar cells are installed on a surface and linked in parallel or series to create solar cell modules or photovoltaic modules that have a higher power output. The equivalent circuit of one diode is used to simulate the photovoltaic cell s. The calculation of the PV current is illustrated in (6).

$$\mathrm{I} = \mathrm{I_{ph}} - \mathrm{I_0}[\mathrm{e}^{(\mathrm{V+IRs})\frac{\mathrm{q}}{\mathrm{nKTNs}}} - 1] - \mathrm{I_{sh}}$$
(6)

where Ns is the number of PV modules connected in series, V is the output voltage of the solar cell, and I0 displays the value of the dark saturation current. k is the Boltzmann gas constant (1.38 10-23 J/K), T is absolute temperature (K), q is electron charge (1.6x10-19 C), and n is the linearity factor.Simulink is used to build the mathematical model of the photovoltaic system with the equations described. Moreover, the system's maximum power point tracking (MPPT) uses the perturb and observe (P&O) technique.

IV. STATIC SYNCHRONOUS COMPENSATOR

Based on a voltage source DC/AC converter, STATCOM operates. At the STATCOM output, balanced three-phase voltages with controlled amplitude and phase angle are produced at the mains frequency. The steady-state power exchange between the device and the AC system in this design is typically reactive. The amplitude and phase angle of the transformer output voltage are adjusted to manage the reactive power exchange between the STATCOM and the AC system. For this, the STATCOM circuit's inverter's ac output voltage frequency and magnitude must be configured. If the STATCOM's output voltage is greater than the AC system voltage (Vstatcom > Vac), the current travels via the transformer reactance and into the AC system.The Reactive power is produced by the device for the transmission line.

The gadget functions in capacitive mode if the STATCOM output voltage is higher than the transmission line voltage. The capacitor is utilised to supply the inverter with the necessary DC voltage. Depending on the phase difference between the inverter output voltage and the AC system voltage, the capacitor is either charged or discharged. In case transformer resistance is ignored, active power flowing from the AC system to STATCOM is depicted in (7).

$$P = \frac{V_{ac}V_{statcom}\sin\alpha}{X} \tag{7}$$

If is greater than 0, the inverter's output voltage is out of phase with the system voltage. Due to P > 0, the capacitor gets charged. The capacitor discharges if 0 as a result of P 0.

Calculating reactive power moving from STATCOM to an AC system or from an AC system to STATCOM (8).

$$Q = \frac{V_{ac}V_{statcom}\cos\alpha - V_{ac}^2}{X} \tag{8}$$

where Vac is the AC system voltage, Vstatcom is the inverter output voltage, X is the equivalent transformer reactance, and is the voltage phase difference.

The STATCOM maintains the voltage Vdc constant while calculating the amplitude of the inverter's AC output voltage by varying the modulation index (ma). The modulation index typically ranges from 0 to ma-1; if ma = 0.75, no power exchange occurs.

$(V_{ac} = V_{statcom})$

In case ma = 0.65; STATCOM is in inductive mode

$(V_{ac} > V_{statcom})$

In case ma = 0.85; STATCOM in capacitive mode

$(V_{statcom} > V_{ac})$

Inverter output voltage in STATCOM can be calculated as shown in (9), (10)

$$V_{statcom} = V_{ef}\frac{\sqrt{3}}{2} \tag{9}$$

$$V_{ef} = V_{dc}\frac{ma}{2} \tag{10}$$

According to (9) and (10), the DC voltage ismaintained constant while the ma value is changed to alter the output voltage of STATCOM.

STATCOM functions either in the capacitiv e or inductive mode for reactive power compensatio n to keep the value of\sthe active and reactive power in the system under grid limits,\sand to prevent trans mission losses. The system is directly linked to the r eactors, as seen in Fig. 3. In Fig. 4, a control circuit f or STATCOM is shown, where ac voltage (Vbus), D C voltage (Vdc), active and reactive current compon ents (Id&Iq), and threephase signals (Va, Vb, Vc) ar e transformed into rotational axis components (Vd a nd Vq) utilising space vector transformations (Park a nd Clarke). The STATCOM control circuit uses PI t o supply the controls, and the PLL is modelled in M atlab/Simulink. Table I lists the parameters used in S TATCOM.

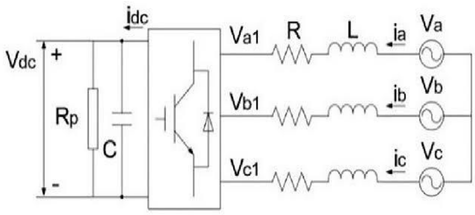


Fig. 4.1. The equivalent circuit of STATCOM.

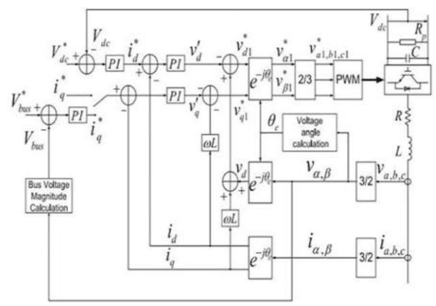


Fig. 4.2. STATCOM control circuit.

TABLE 4.1. SYSTEM PARAMETERS OF STATCOM MODEL.

Parameter	Numerical Value
Grid line voltage	25 kV
Equivalent resistor	0.0012 Ω
Equivalent inductor	1.2 mH
Shunt capacitor	16000 μF
Capacitor voltage	2400 V
System frequency	60 Hz

Fig. 5 displays the suggested hybrid system design that was modelled in Simulink. A distribution system with a 25 kV 100 MVA was employed and lines with a length of 21 km\sand 2 km were used to carry electricity to linked loads at\sbusbar2 and busbar3, respectively. The rotor side and grid side control of a double-fed induction generator based on a wind turbine were carried out. In order to provide the most torque given the wind speed, an indirect MPPT approach was employed. A 0.4 MW PV system was modelled and synchronisation control with PLL was done. For the purpose of decreasing voltage fluctuation at the end of the busbar and compensating for reactive power, the STATCOM was introduced at the point of common connection. the voltage, current, and active and reactiveFirst, power levels at the end of the busbar for the system without STATCOM are measured. For voltage control, a STATCOM with a 3 MVAR rating was included into the same PCC. A variable load between 1 MVA and 5.2 MVA was used at the end of the line in the hybrid system with STATCOM. To maintain the reference voltage at 1 p.u., the STATCOM system is configured at 1.077 p.u.

In this work, the voltage stability of the PI controller in the STATCOM control circuit is assessed using the time domain criterion. The characteristics of the control system may degrade and the system may become unstable if the controller tuning constants have an incorrect value. Because of this, correct tuning constant selection and controller parameter optimization are crucial to the effective operation of this control.

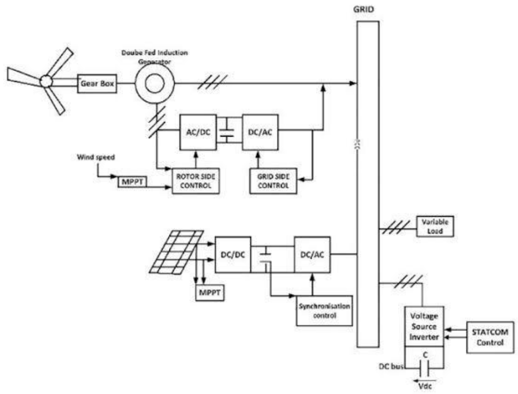


Fig.4.3. Solar-wind hybrid system including STATCOM

ITAE is the most typical performance criteria (integral absolute time error). The IAE's negative aspect.While the minimization technique results in a relatively low IAE (integral absolute error) and ISE (integral square error) requirements, the transient responsiveness is poor. Using ITAE or ITSE (integral time square error), this drawback is overcome [19]. The ITAE performance criteria from equation (11) is employed as the objective function for optimization in this study. Table II contains the optimization's findings. The writing of genetic algorithm codes that are compatible with the m-function code file and a decent optimization with the right values for restriction, multiplication, mutation, and population size have been done. The eight variables in the Matlab m-function file are optimised using an eight-dimensional search.The relationship between space, Kp, and Ki values is established using certain lower and higher bounds.

$$\mathrm{ITAE}=\int_0^{\infty} t|e(t)d(t) \quad (11)$$

GA-based approach

Using the following three stages is how genetic programming starts to solve issues:

1. Identifying the fitness function;

2. Coding (genetic coding);

3. Choosing a random sample of the population from which to start.

TABLE 4.2. CONTROLLER GAIN CONSTANTS IN STATCOM FOR ITAE.

ITAE	For AC Regulator		For DC Regulator		For (Id&Iq) current regulator	
PI constants	Kp1	Ki1	Kp2	Ki2	Kp3 Kp4	Ki3 Ki4
GA results	0.3747	0.5694	0.0114	0.8051	0.9748 0.4292	0.3043 0.7021

The fitness function of every member of the population is estimated after repeated iterations until a good enough solution is obtained. The finest individuals are chosen to make up the new generation, which is then produced through crossing and mutation. The population gains the next generation (chromosomes), and the ideal answer is discovered. The optimal value of the Kp (proportional) and Ki (integral) constants for STATCOM in ITAE is determined using a genetic algorithm as the fitness function. The genetic algorithm starts with Kp and Ki, which are computed using the usual technique. The process for utilising GA to optimise the Kp and Ki gain constant values for STATCOM is shown in the flow chart of Fig. 6.

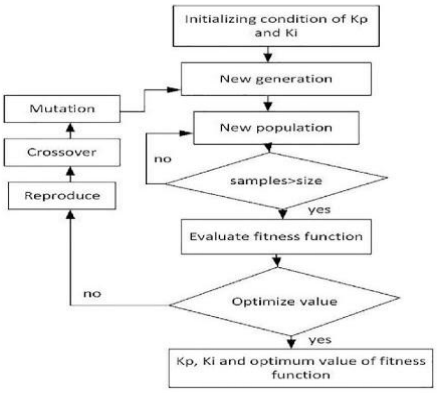


Fig. 4.4. Flow chart for STATCOM tuning using GA

V.SIMULATION RESULTS AND DISCUSSION

The effect of distribution networks on the quality of the power rises when more solar PV and wind generating facilities are connected to the grid [4]. These power quality issues brought on by renewable energy sources often include harmonics, frequency imbalances, abrupt voltage shifts, voltage collapses, and sluggish voltage variations. Voltage fluctuations are one of the most glaring issues with the integration of solar PV and wind power systems into the network.The control strategy used by STATCOM has reduced voltage fluctuation, and STATCOM has also improved the voltage profile and compensated for reactive power.

A. Simulation Results of STATCOM for Power Factor Compensation.

As shown in Fig.5.1, when the system was tested, the magnitude of the voltage source rose by 0.2 seconds. STATCOM adjusted for this voltage by absorbing +2.7 MVAR of reactive power.

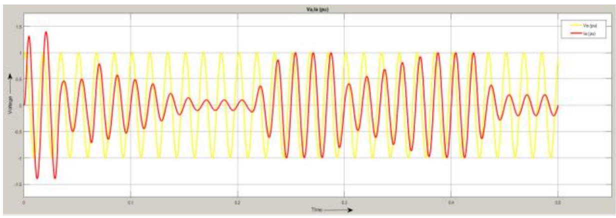


Fig 5.1 STATCOM output voltage profile

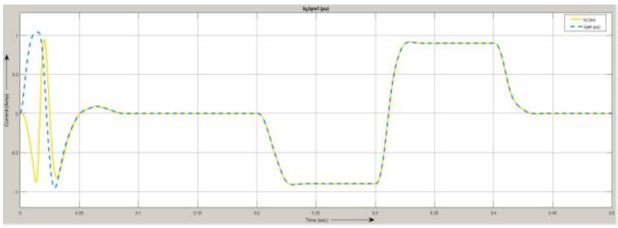


Fig 5.2 Ip,Iq current component of STATCOM

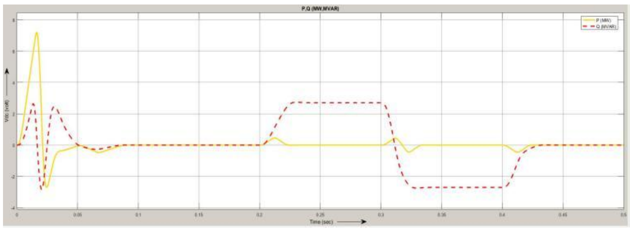


Fig 5.3 Absorbed active and reactive power by STATCOM

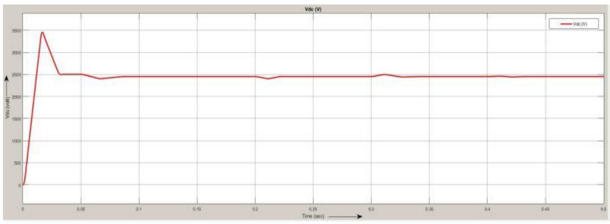


Fig 5.4 DC voltage

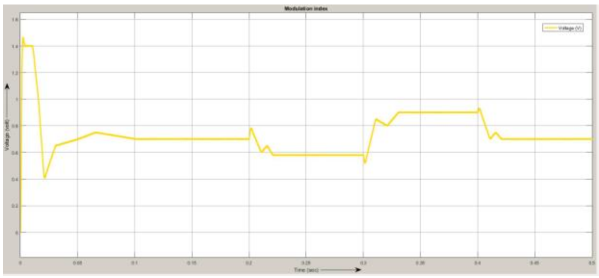


Fig 5.5 Modulation index wave forms

As illustrated in Fig 5.1, DSTATCOM created reactive power while preserving the voltage value by shifting the reactive power from +2.7 to -2.7 MVAR when the magnitude of the voltage source was lowered at 0.3 seconds in fig 5.2. As demonstrated in Fig.5.3, DC voltage is sought to be kept constant and the modulation index is mentioned in Fig 5.4. Starting at 0.2 seconds, STATCOM functions in the inductive mode (ma = 0.65), while switching to the capacitive mode (ma = 0.85), where reactive power is produced, at 0.3 seconds. The simulations were run for a duration of 0.5 seconds.

B. Simulation Results of Solar-Wind Hybrid System with STATCOM for Reactive Power Compensation

The hybrid micro-grid system firstly operates without STATCOM incorporation, and it can be reflected in Fig. 5.6 that at the end of the busbar, the voltage value increases to 1.08 p.u. at 0.2 seconds and decreases to 0.92 p.u. at 0.3 seconds. A voltage fluctuation between ±10 % can be clearly seen. In the hybrid system incorporating STATCOM, the voltage is maintained at 1 p.u. at all points in Fig. 5.7, and the fluctuation between 0.2 seconds and 0.4 seconds is reduced by ±8 %. In Fig. 5.8, the graphs for the ITAE performance criterion show that the PI controller has the highest overshoot and

peaks at some points, the voltage profiles of the GA reaches a point of 1 p.u. at 0.05 s and have a lower overshoot, and the voltage fluctuation is minimized. From the figure, better response and voltage stability can be observed as a result of GA optimization. The results show that optimal adjustment of controller parameters and proper selection of tuning constants have an important role in the proper performance of this control.

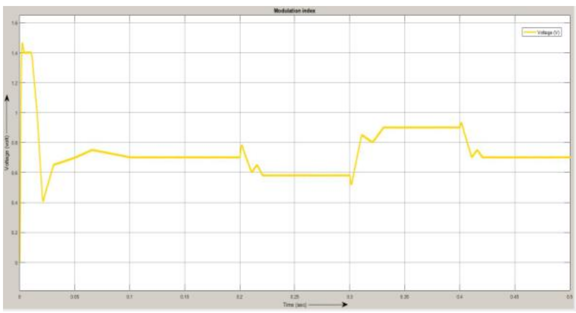


Fig 5.6 . *Voltage profile at the end of the busbar without STATCOM*

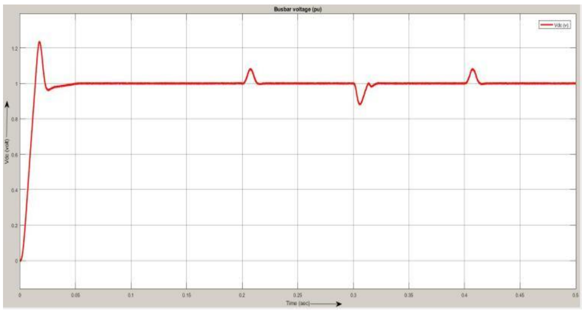


Fig. 5.7. Voltage profile at the end of the busbar without STATCOM ;voltage profile at the end of the busbar for conventional PI controller, GA optimized controller, with STATCOM (p.u.).

At 0.3 seconds, the magnitude of the voltage source decreased, but DSTATCOM continued to maintain the voltage by producing reactive power.

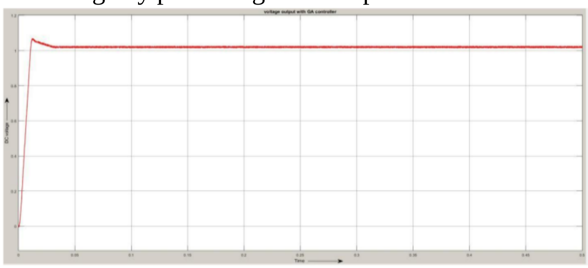


Fig 5.8 Voltage profile at the end of the busbar with using GA controllers.

DC voltage is tried to be kept constant and the modulation index is referred. STATCOM operates in inductive mode beginning from 0.4 seconds (ma = 0.65), whereas at 0.5 sec in capacitive mode (ma = 0.85), in which reactive power is generated, the simulations were carried out for a time period of 0.5 sec, from Fig 4.12 the fluctuation between 0.4 seconds and 0.5 seconds is reduced, The voltage profiles of the GA reaches a point of 1 p.u. at 0.05 s and have a lower overshoot, and the voltage fluctuation is minimized. From the Fig 4.12, better response and voltage stability can be observed as a result of GA optimization. The comparisons of the results showed that the effectiveness of the STATCOM tuned with GA was improved

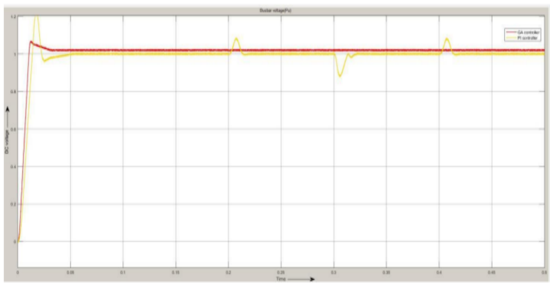


Fig 5.9 voltage profiles comparisons of both PI controller and GA controller

In this study, the impacts of a 2 MW wind power induction generator based wind generation system and a 0.4 MW solar power generation system on the grid was investigated. For this hybrid system, it has been pointed out that STATCOM provides reactive power compensation. A solar PV-wind power system with a hybrid structure was designed and the voltage profiles at the output were examined. STATCOM was incorporated to study the voltage profiles in the system according to capacitive and reactive operating states. On this basis, this work pointed out that power instability in large transmission systems can be minimized, and the fluctuations caused by the adoption of renewable energy sources to the system can be diminished.The comparisons of the results showed that the effectiveness of the STATCOM tuned with GA was improved. By acquiring the best values for PI controller gains, voltage swell occurred due to the change in reactive power has been overcome and a better dynamic response was reached.

VI. CONCLUSIONS

On this study, Voltage control and stability for Solar PV -Wind energy hybrid Micro-Grid using optimized STATCOM is investigated. In this study, a 2MW wind turbine based DFIG and a 0.4MW solar PV energy system are hybridized & this hybrid system is provided with STATCOM which provides reactive power compensation STATCOM was incorporated to study the voltage profiles in the system according to capacitive and reactive operating states. On this basis, this work pointed out that power instability in large transmission systems can be minimized, and the fluctuations caused by the adoption of renewable energy sources to the system can be diminished. When the results from both STATCOM based PI controller and GA are compared GA is providing better voltage stability and reduced voltage fluctuations. On basis of this work, reduced voltage fluctuations, voltage stability and reactive power compensation can be obtained in large transmission systems when Renewable Energy Sources are used as power sources.

REFERENCES

[1]. Valenciaga F., Puleston PF, Battiaiotto PE. «Power control of a photovoltaic array in a hybrid electric generation system using sliding mode techniques». IEE Proc-Control Theory Appl 2001; 148(6):P 448–55.

[2]. Mirecki, A "Comparative study of enery conversion system dedicated to a small wind turbine', Etude comparative de chaînes de conversion d'énergie dédiées à une éolienne de petite puissance", Phd Thesis, Institut national polytechnique de Toulouse, 2005.

[3]. Il-Song Kim "Sliding mode controller for the single-phase grid-connected photovoltaic system" Applied Energy 83 (2006) 1101–1115.

[4]. F. Katiraei, M. R. Irvine, A. L. Dimes, and N. D. Hatziargyriou, "Micro grids management: control and operation aspects of micro grids," IEEE Power Energy Mag., vol. 6, no. 3, pp. 54-65, May/Jun. 2008.

[5]. Sofia, L. "Study, control and simulation of a hybrid chain for the production of electrical energy, Etude, commande et simulation d'une chaine hybride (photovoltaïque-éolienne) de production d'énergie électrique", Phd Thesis, Université A. Mira-Bejaia, Algerie, 2009.

[6]. Noroozian, Abedi, Gharehpetian Hosseini. Combined operation in DC isolated distribution and PV systems for supplying unbalanced AC loads.RenewableEnergy2009.

[7]. W. Jiang and B. Fatima, "Active current sharing and source management in fuel cell-battery hybrid power system," IEEE Trans. Ind. Electron., vol. 57, no. 2, pp. 752–761, Jan. 2010.

[8]. L. Us and D. Chen, "Control and operation of a DC micro grid with variable generation and energy storage," IEEE Trans. Power Del., vol. 26, no. 4, pp. 25 I 3-2522, Oct. 2011.

[9]. Bingül, Z. and Karahan, O. "A fuzzy logic controller tuned with GA for 2 DOF robot trajectory control», Expert Systems with Applications, Vol. 38, pp. 1017–1031, 2011.

[10]. B.Indurani, Saravana Ilango, and Nagamani,"Control Strategy of Management of power flow in the PV system supplies DC loads," IEEE Trans. Industrial Electronics, vo 60 ,no.3,Aug.2013,pp. 3185-3194.

[11]. Jasim. f. s. "Modelling, design and implementation of d-q control in single-phase grid-connected inverters for photovoltaic systems used in domestic" Phd Thesis, De Montfort University for the award of Doctor of Philosophy 2013.

[12]. Gao Chen, Qiang Yang, Ting Zhang, Zhejiang Bao, and Wenjun Yan, "Real time wind power stabilization approach based on hybrid energy storage systems," 2013 Sixth International Conference of Computational Intelligence, pp.124-129, October, 2013.

[13]. T. Zhang, Z. J. Bao, G. Chen, Q. Yang, W. J. Yan, "Control Strategy for a Hybrid Energy Storage System to Mitigate Wind Power Fluctuations," Sixth International Conference of Computational Intelligence, pp.27-32, October, 2013.

[14]. Jin C, Wang P, Xiao J, "Implementation of hierarchical control in DC micro grids ,"IEEE Transaction of Industrial Electronics, vol.61(8), pp.4032-4042,2014.

[15]. L. Xiao an, J. M. Guerrero, S. Kai, and J. C. Vasquez, "An Improved Droop Control Method for DC Micro grids Based on Low Bandwidth Communication With DC Bus Voltage Restoration and Enhanced Current Sharing Accuracy," Power Electronics, IEEE Transactionson,vol.29,pp.1800-1812,2014.

[16]. Anastasios, P.K., Dounis, I., Papadakis, G. and Assimakopoulos, M.N. "An intelligent MPPT controller based on direct neural control for partially shaded PV system", Energy and Buildings, 90, pp. 51–64, 2015.

[17]. Abdelhalim Borni, Noureddine Bouarroudj, Abdelhak Bouchakour and Layachi Zaghba "P&O-PI and fuzzy-PI MPPT Controllers and their time domain optimization using GA and GA for grid-connected photovoltaic system: a comparative study" International Journal of Power Electronics, 8(4): 300–322, 2017.

[18]. Borni, T. Abdelkrim, L. Zaghba, A. Bouchakour, A. Lakhdari, and L. Zarour, "Fuzzy logic, PSO based fuzzy logic algorithm and current controls comparative for grid-connected hybrid system", AIP Conference Proceedings, Volume 1814, Issue 1

[19]. Abdelhalim Borni, Tameur Abdelkrim, Noureddine Bouarroudj, Abdelhak Bouchakour, Layachi Zaghba, Abdelkader Lakhdari and Laid Zarour "Optimized MPPT Controllers Using GA for Grid Connected Photovoltaic Systems, Comparative study" Energy Procedia 119(2017) 278–296.

[20]. Il-Song Kim "Sliding mode controller for the single-phase grid-connected photovoltaic system" Applied Energy 83 (2006) 1101–1115.