Configuration and Voltage Control of a Solar-Wind Hybrid Microgrid Employing STATCOM with Fuzzy Logic Controller

Ungati vasudevarao rao (Research Scholar) [1], V.Vykunta Rao (Assistant Professor) [2]
Konni. Seetharamayya (Assistant Professor) [3]
SRI VENKATESWARA COLLEGE OF ENGINEERING AND TECHNOLOGY NH-16, ETCHERLA, SRIKAKULAM, (A.P)-532410

Abstract

The ability of wind and solar photovoltaic (PV) systems to generate electricity is heavily dependent on weather conditions. Their output fluctuates due to their intermittent nature. As a result, the requirement for energy transmission and distribution systems to compensate quickly is becoming increasingly crucial for this reason fuzzy logic controller is used to better results. The Static Synchronous Compensator (STATCOM) is a device that can be used to compensate for reactive power and reduce voltage fluctuations generated by the system and renewable energy sources. This research looks at how to simulate a Solar PV-Wind Hybrid Micro-grid and how to raise the system's stable working limit with the addition of STATCOM. The main contribution of this research is the use of genetic algorithms (GA) to optimize the gain parameters of four PI controllers in STATCOM, resulting in superior responses and voltage stability in the nonlinear nature of a solar-wind hybrid micro-grid. A 2 MW wind turbine model based on a doubly fed induction generator (DFIG), a 0.4 MW solar PV power system model, and a 3 MVAR STATCOM are among the Simulink models of the system design. The voltage fluctuation at the end of the bus bar is reduced by 8% when utilising a traditional PI controller, according to certification. The results of Fuzzy logic controller optimization are compared to those of a traditional controller and a GA-based PI controller, and better results are produced.

Index Terms: Flexible AC transmission systems (FACTS); Genetic Algorithm; PV-Wind hybrid system; Static synchronous compensator; Voltage control.

I. INTRODUCTION

Renewable energy applications have grown in popularity, particularly in recent years. Increasing energy use, significant advancements in energy production technology and growing public awareness of environmental issues are driving research into alternative energy and distributed production. For applications with minimal installed capacity, a hybrid structure comprising of an efficient photovoltaic (PV) system and a wind energy system can be created utilising various control techniques. Because renewable energy systems, such as wind alone and hybrid Wind/PV, are not totally safe in terms of satisfying load demand, power instabilities occur, and reactive power compensation is an emerging need for a hybrid system's stable operation. In all energy systems, reactive power adjustment is needed. Reactive power is associated with a variety of power quality issues as well as increased power losses.

Synchronous condensers and permanent mechanical switching capacitors have been utilized to overcome this problem for many years. This sort of compensation has some drawbacks, such as enormous dimensions, excessive losses, and a poor response time. The FACTS (Flexible Alternating Current Transmission Systems) devices were commercially introduced in the late 1980s for reducing power quality issues, enhancing system stability, and increasing power transfer capability [1]. New FACTS topologies, on the other hand, are emerging to improve the security and stability of microgrids [2], [3]. STATCOM is a shunt-connected inverter-based device that enhances power quality in alternating current systems and is part of the FACTS family of devices.

In 1991, the STATCOM was installed for the first time in Japan. It had a ±80 MVAR voltage stabilization rating [1]. Advanced and complex control algorithms have been possible to construct with the debut of real-time controllers [4]. Power factor enhancement, load balancing, voltage control, and harmonic reduction are all functions of these devices in energy systems. The need for additional lines is reduced by boosting the capacity of existing transmission lines. To keep the power system within the required operating limits, various control mechanisms are employed.

Proportional-Integral (PI), Proportional-Integral-Derivative (PID), Fuzzy Logic Controller (FLC), and Artificial Neural Networks (ANN) based controllers are the most often used controllers. Traditional PI type controllers are commonly used in commercial STATCOM devices, and the controller's effectiveness dictates STATCOM's performance. As a result, the current study aims to improve the reliability and adaptability of STATCOM for hybrid power system variations.

In recent years, various researches on STATCOM have been made. In 2010, it is carried out research on a hybrid PV-Wind supply system with STATCOM interface for a water-lift station and reduced voltage fluctuation in a limited manner [5]. In the literature, some studies have discussed the impact of FACTS controllers on the stability of power systems connected with doubly fed induction generators and focused on the results of rotor angle responses [6]. The use of conventional and direct-current vector control schemes has been proposed as a control mechanism for VSC (voltage source control)-based STATCOM. However, it only operated with the system's voltage fluctuations, not a hybrid system [7].

Describes voltage control for a hybrid power system based on a wind energy conversion technology with reactive power support. However, STATCOM was not used to decrease voltage fluctuations in the load side converter in this study. [9] Describes the use of a parallel-resonance bridge type fault current limiter (PRBFCL) to improve the transient stability of a hybrid power system and reduce voltage fluctuation. According to the literature study, relatively little research has been done on the STATCOM system-based voltage fluctuations generated by the hybrid solar-wind microgrid. With the growing use of PV and wind power systems, traditional FACTS devices still need to be improved through controller

ISSN: 2278-4632
Vol-12 Issue-01 No.01: 2022

optimizations and considerable analysis under various operating situations is required.

The dynamic response of hybrid power systems was studied in reference [10] using the STATCOM optimum gain setting. The use of SVC and an Automatic Voltage Regulator was suggested in reference [11]. (AVR) The evolutionary method is utilized to solve an optimization issue while also obtaining the SVC and AVR PI control settings. For the isolated hybrid power system model-performance analysis of a Takagi-Sugeno fuzzy logic (SOA-TSFL) based controller, reference [12] used a searcher optimization approach.

The objective of this article is to incorporate STATCOM for reactive power compensation to boost the reliability of the presented power system design. It also aims to lower voltage fluctuations caused by renewable energy sources' fluctuating nature. To get a good response, optimal PI parameter adjustments in STATCOM are conducted automatically based on GA. In the STATCOM control circuit, optimization of the PI controller parameters is done. To the best of the authors' knowledge, no research has been published on the optimization and adjustment methods of four PI controllers in the STATCOM control circuit for PV-Wind hybrid system voltage stability.

II. WIND POWER SYSTEM MODELLING

One of the most popular wind generators today is the Doubly Fed Induction Generator (DFIG) [13]. DFIG is made up of stator windings that are directly connected to a fixed frequency 3-phase network and rotor windings that have back-to-back voltage-based converters. The word "doubly -fed" refers to a system in which the stator voltage comes from the mains while the rotor voltage is induced by the power converter. The method allows for significant but limited variable speeds (a speed differential of up to ± 40 % can be achieved). By injecting varying frequencies of current into the rotor, the transducers alter the mechanical and electrical frequency. Power converters or controllers influence the behaviour of generators in both normal and abnormal operation [14]

The DFIG is made up of a series of voltage-induced converters that are bi-directionally coupled to the rotor windings and are connected directly to the fixed frequency three-phase grid. The rectifier on the rotor side and the inverter on the grid side control each other in the power converter unit. The fundamental aim is to manage the active and reactive powers of the rectifier's rotor current components on the rotor side. On the grid side, the inverter controls the DC link voltage and guarantees that the converter's functioning is integrated with the power factor.

DFIG has a number of advantages, including the ability to adjust active and reactive power using rotor current [14]. In Fig. 1, it has two sequential converters for rotor and grid side control. Vbus (grid voltage), Q (reactive power component), and three-phase current component (Ia, Ib, Ic) are taken into consideration in the grid side control circuit of the wind, and Vbus and Id&Iq are regulated. Voltage and current components (Vd & Vq) are converted to three-phase signals via space vector transformations. The angles are calculated using voltage values and employed in space vector transformations using PLL (Park and Clarke).

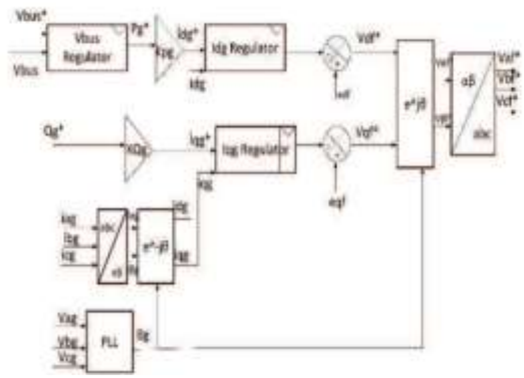


Fig.1. Grid side control circuit.

In the Simulink environment, the control circuit is created. The aerodynamic model calculates the mechanical torque as a function of airflow on the blades [15], which is used to represent the rotor's power. The average speed on the area swept by the blades is referred to as wind speed (Vw). The power equation generated by a wind turbine is as follows: (1)

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

The amount of aerodynamic torque is given in (2)

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

Wind turbine end velocity ratio is given in (3)

$$\partial = R\Omega_t / V_w. \qquad (3)$$

Power coefficient (Cp) refers to the analytical expression as a function of the angle of inclination (β) and the turbine end velocity ratio (∂), k is a constant, R is ratio, Ct is the coefficient of torque, A is surface, r is the air density, Wt is the angular speed of the rotor. The power factor equation is given in (4) and (5) [15]:

$$C_p = k1\left(\frac{k2}{\partial i} - k3\beta - k4\beta^{k5} - k6\right)\left(\frac{e^{\left(\frac{k7}{\partial i}\right)}}{1}\right). \qquad (4)$$

$$\partial i = 1/(\partial + k8). \qquad (5)$$

The characteristics in Fig. 1 are based on these equations. There are two of them. When the wind speed is 12 m/s, the output power reaches 2 MW, as shown in the diagram. A wind turbine model is created using these power and torque equations, and indirect speed control is used to obtain the maximum power point. Some data from the Doubly Fed Induction Machine was used to model a DFIG [15].

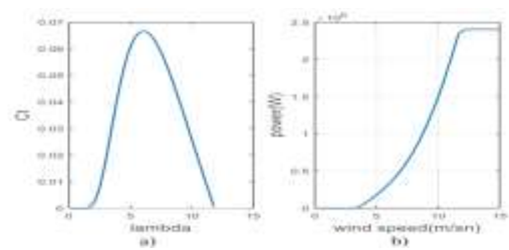


Fig.2. Characteristics of wind turbine: a) λ-Ct characteristic; b) Velocity- Power (v-P) characteristics.

III. PHOTOVOLTAIC POWER SYSTEM MODELLING

By converting the energy in the sun's rays, solar PV panels assure the generation of electricity in DC form. Many solar cells are connected in parallel or series and mounted on a surface to make a solar cell module or a photovoltaic module to maximize the power output. The one-diode equivalent circuit is used to represent the PV cells. As illustrated in, the PV current can be calculated (6) [16]

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

where k is Boltzmann gas constant (1.38 × 10-23 J/K), T is absolute temperature (K), q is electron charge (1.6x10-19 C), n is linearity factor, Rs is the series resistance, Rsh is the cell shunt resistance, Ns is number of PV module in series, V is the output voltage of solar cell and I0 shows the dark saturation current value. Simulink is used to create the mathematical model of the photovoltaic system using the equations provided in [16]. In addition, the system's maximum power point tracking (MPPT) is implemented using perturb and observe (P&O) algorithm.

IV. STATIC SYNCHRONOUS COMPENSATOR:

A voltage source DC/AC converter is used in STATCOM. Balanced three-phase voltages with controlled amplitude and phase angle are obtained at the STATCOM output at the mains frequency. The AC system and the device's steady-state power exchange are often reactive in this embodiment. Controlling the magnitude and phase angle of the transformer output voltage controls the reactive power exchange between the STATCOM and the AC system. In the STATCOM circuit, the magnitude and frequency of the inverter's ac output voltage must be tuned for this. If the STATCOM's output voltage is greater than the AC system voltage (V statcom > Vac), current flows from the STATCOM to the AC system via transformer reactance, generating reactive power for the transmission line.

The equipment performs in capacitive mode if the STATCOM output voltage exceeds the transmission line voltage. The DC voltage required by the inverter is provided by the capacitor. The phase difference between the inverter output voltage and the AC system voltage determines whether the capacitor is charged or discharged. In the absence of transformer resistance, active power flowing from the AC system to STATCOM is depicted in (7) [17].

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

If α > 0, the inverter output voltage is in phase opposition with the system voltage. The capacitor is charged because of P > 0. If α < 0, the capacitor is discharged because of P < 0. Reactive power flowing from STATCOM to AC system or from AC system to STATCOM can be calculated by (8)

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

Where Vac is AC system voltage, Vstatcom is inverter output voltage, X is equivalent reactance of transformers, α is the phase difference between voltages. In the STATCOM, the voltage Vdc is kept constant and the amplitude of the AC output voltage of the inverter is calculated by changing the modulation index (ma). The modulation index is usually between 0 < ma<1.

In case m_a = 0.75; there is no power exchange $(V_{ac} = V_{statcom})$

In case m_a = 0.65; STATCOM is in inductive mode $\left(V_{ac} > V_{statcom}\right)$.

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 output voltage of STATCOM is adjusted by keeping the DC voltage constant and changing the ma value. STATCOM operates either in the capacitive or inductive mode for reactive power compensation to keep the value of the active and reactive power in the system in grid limits, and to prevent transmission losses. As shown in Fig. 3, the system is connected directly to the reactors. In Fig. 4, a control circuit belonging to STATCOM is given and ac voltage (Vbus), DC voltage (Vdc), active and reactive current components (Id&Iq) are regulated and three-phase signals (Va, Vb, Vc) using space vector transformations (Park and Clarke) is converted into rotating axis components Vd and Vq. The controls are provided with the PI controller and STATCOM control circuit using PI, PLL is modeled in Matlab/Simulink. The parameter used in STATCOM is shown in Table I.

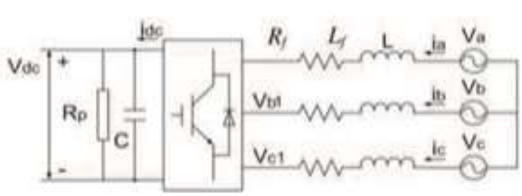


Fig. 3. The equivalent circuit of STATCOM

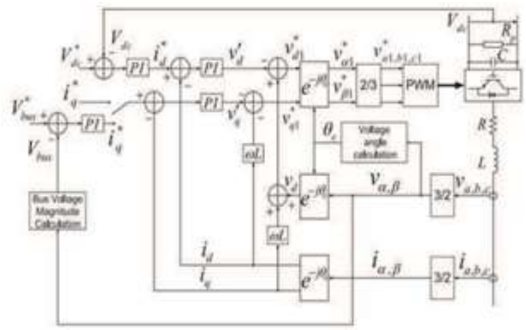


Fig. 4. STATCOM control circuit [18]

TABLE I. 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

Figure 5 depicts the proposed hybrid system architecture as modelled in Simulink. To transfer power to associated loads at busbar2 and busbar3, respectively, a distribution system with a 25 kV 100 MVA and lines with lengths of 21 km and 2 km were employed. The rotor side and grid side control of a double-fed induction generator based on a wind turbine were performed. According to wind speed and best torque output, an indirect MPPT approach was adopted. A 0.4 MW PV system was simulated and PLL-based synchronization control was implemented. The STATCOM was installed at the point of common coupling to reduce voltage fluctuations at the busbar's end and to compensate for reactive power.

For the system without STATCOM, the current, voltage, active and reactive power levels at the end of the bus bar are first measured. For voltage regulation, a 3 MVAR STATCOM was included into the same PCC. A

ISSN: 2278-4632
Vol-12 Issue-01 No.01: 2022

variable load between 1 MVA and 5.2 MVA was used at the end of the line in the hybrid system with STATCOM. The STATCOM system has been set at1.077 p.u to maintain a 1 p.u. reference voltage the time domain criterion is employed in this work to evaluate the voltage stability of the PI controller in the STATCOM's control circuit. As a result, proper tuning constant selection and optimal controller parameter adjustment are essential to the control's operation and maintenance.

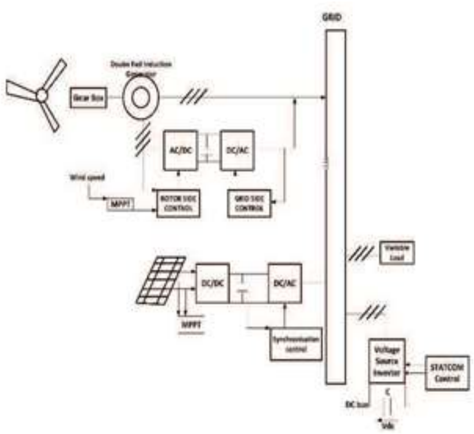


Fig. 5. Solar-wind hybrid system including STATCOM

ITAE is the most common performance criterion (integral absolute time error). The drawback of the IAE (integral absolute error) and ISE (integral square error) criteria is that the transient performance is poor while the reduction process is relatively low. ITAE or ITSE (integral time square error) [19] are used to overcome this problem. The ITAE performance criterion (11) is used as the objective function for optimization in this study.

Table II shows the results of the optimization. Genetic algorithm codes suitable with the m-function code file have been written, and a good optimization with the correct restriction, multiplication, mutation, and population size values has been carried out. The Matlab m-function file optimizes eight variables in an eight-dimensional search space, with Kp and Ki values specified by particular lower and upper constraints.

$$ITAE = \int_{0}^{\infty} t\left|e(t)\right| d(t), \tag{11}$$

GA based method

Three steps are followed by genetic programming to address a problem:

1. Identification of fitness function;

2. Coding (genetic coding);

3. Selecting the starting population to be random individuals.

TABLE II. 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 process is repeated until a satisfactory solution is discovered, and the fitness function of the entire population is determined. The best individuals are chosen for the new generation, and crossing and mutation are used to establish a new generation. The population is refreshed with a new generation (chromosomes), and the optimal solution is discovered.

The best value of Kp (proportional) and Ki (integral) constants for STATCOM in ITAE as a fitness function is determined using a

ISSN: 2278-4632
Vol-12 Issue-01 No.01: 2022

genetic algorithm. The starting operators for the genetic algorithm are Kp and Ki, which are estimated using a traditional technique. The technique for enhancing the value of the Kp and Ki gain constants for STATCOM using GA is depicted in Fig. 6.

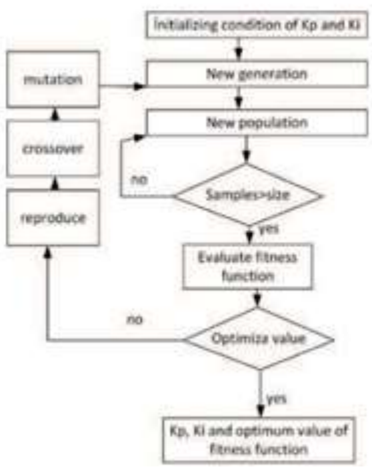


Fig. 6. Flow chart for STATCOM tuning using GA

II. SIMULATION RESULTS AND DISCUSSION

The impact of distribution networks on power quality increases as more solar PV and wind power plants are connected to the grid [4]. Slow voltage variations, voltage collapses, fast voltage changes, harmonics, and frequency imbalances are common power quality issues induced by renewable sources. Voltage fluctuations are one of the most noticeable issues with the integration of solar PV and wind power systems into the grid. The voltage fluctuation has been decreased by STATCOM's control system, and STATCOM has improved the voltage profile and compensated for reactive power.

A. Simulation Results of STATCOM for Power Factor Compensation

The magnitude of the voltage source was increased by 0.2 seconds when the system was tested, as shown in Fig. 7(a), and STATCOM adjusted for this voltage by absorbing +2.7 MVAR of reactive power.

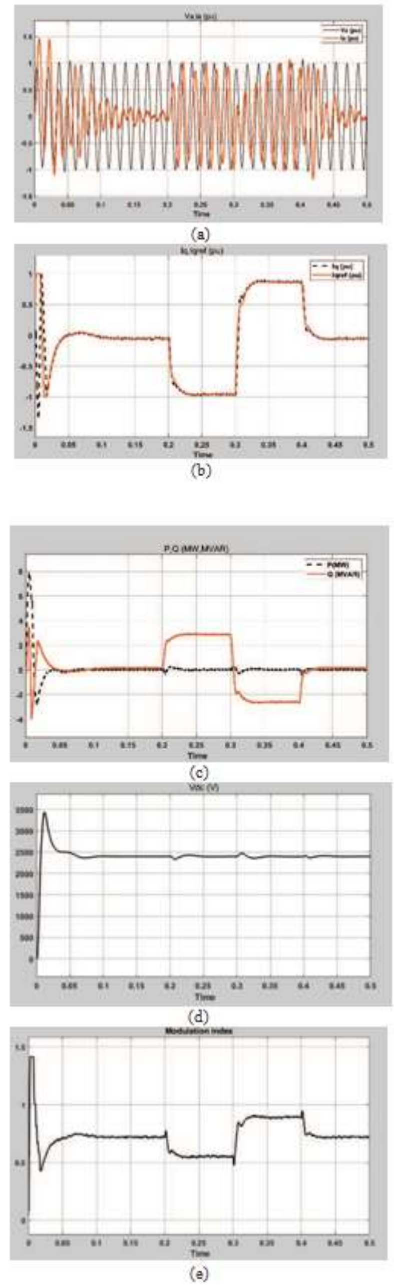


Fig. 7. STATCOM output voltage profile (a); reactive current component of STATCOM (b), produced or absorbed active and reactive

ISSN: 2278-4632
Vol-12 Issue-01 No.01: 2022

power by STATCOM (c), DC voltage (d), modulation index waveforms (e).

DSTATCOM generated reactive power while preserving the voltage value by shifting the reactive power from +2.7 to -2.7 MVAR at 0.3 seconds, as illustrated in Fig. 7. (c). DC voltage is attempted to be kept constant, as illustrated in Fig. 7(d), and the modulation index is referred to in Fig. 7(e). STATCOM operates in inductive mode (ma = 0.65) for the first 0.2 seconds, then switches to capacitive mode (ma = 0.85) for the next 0.3 seconds, generating reactive power. For a total of 0.5 seconds, the simulations were run.

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

The hybrid micro-grid system first functions without STATCOM, as shown in Fig. 8(a), where the voltage value increases to 1.08 p.u. at 0.2 seconds and drops to 0.92 p.u. at 0.3 seconds. A voltage variation of about ±10% can be seen clearly. The voltage is maintained at 1 p.u. in the hybrid system with STATCOM at all points in Fig. 8(b) and the variation between 0.2 seconds and 0.4 seconds are decreased by ±8%.

The graphs for the ITAE performance criterion in Fig. 8(b) indicate that the PI controller has the highest overshoot and peaks at some points, whereas the voltage profiles of the GA reach a point of 1 p.u. at 0.05 s, have a smaller overshoot, and have the least voltage fluctuation. As can be seen in the diagram, GA optimization improved response and voltage stability. The results show that accurate tuning constant selection and optimal controller parameter modification play a vital role in the proper operation of this control.

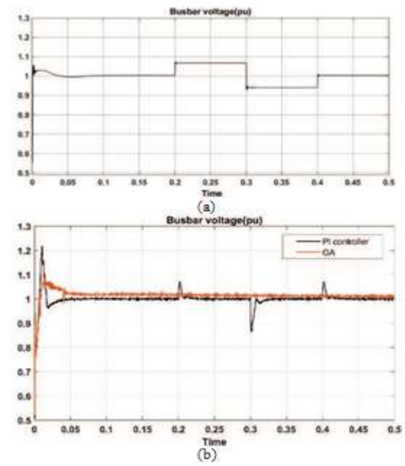


Fig. 8. Voltage profile at the end of the bus bar without STATCOM (a); voltage profile at the end of the bus bar for conventional PI controller, GA optimized controller, with STATCOM (p.u.) (b).

FUZZY LOGIC CONTROLLER:

A set of linguistic principles governs basic control action in FLC. The system establishes these regulations. In FC, mathematical modelling of the system is not necessary because numerical variables are translated to linguistic variables. Fuzzification, interference engine, and defuzzification are the three sections of the FLC. The FC is defined as follows: i. each input and output has seven fuzzy sets. ii. For simplicity, triangular membership functions are used. iii. The use of a continuous universe of discourse for fuzzification. iv. Mamdani's "min" operator is used to infer. v. Using the "height" approach to defuzzify.

Fuzzification:

Membership function values are assigned to the linguistic variables, using seven fuzzy subsets: NB (Negative Big), NM (Negative Medium), NS (Negative Small), ZE

ISSN: 2278-4632
Vol-12 Issue-01 No.01: 2022

(Zero), PS (Positive Small), PM 5 (Positive Medium), and PB (Positive Big). The partition of fuzzy subsets and the shape of membership CE (k) E (k) function adapt the shape up to appropriate system. The value of input error and change in error are normalized by an input scaling factor

ΔE / E	NB	NM	NS	Z	PS	PM	PB
NB	NB	NB	NB	NB	NM	NS	Z
NM	NB	NB	NB	NM	NS	Z	PS
NS	NB	NB	NM	NS	Z	PS	PM
Z	NB	NM	NS	Z	PS	PM	PB
PS	NM	NS	Z	PS	PM	PB	PB
PM	NS	Z	PS	PM	PB	PB	PB
PB	Z	PS	PM	PB	PB	PB	PB

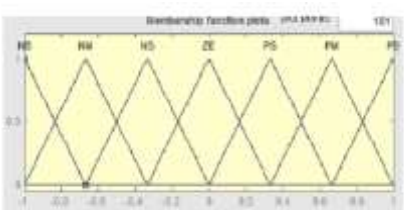
In this system the input scaling factor has been designed such that input values are between -1 and +1. The triangular shape of the membership function of this arrangement presumes that for any particular E(k) input there is only one dominant fuzzy subset. The input error for the FLC is given as

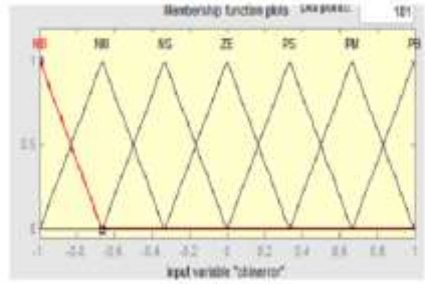
$$E(k) = \frac{P_{ph(k)} - P_{ph(k-1)}}{V_{ph(k)} - V_{ph(k-1)}}$$

$$CE(k) = E(k) - E(k-1)$$

Interference Method:

Several composition methods such as Max–Min and Max-Dot have been proposed in the literature. In this paper Min method is used. The output membership function of each rule is given by the minimum operator and maximum operator. Table 1 shows rule base of the FLC.





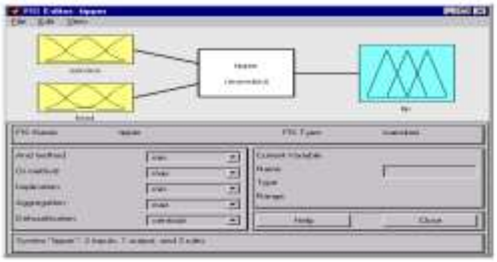
MEMBERSHIP FUNCTIONS

Defuzzification:

As a plant usually requires a non-fuzzy value of control, a defuzzification stage is needed. To compute the output of the FLC, „height" method is used and the FLC output modifies the control output. In recent years, the number and variety of applications of fuzzy logic have increased significantly. The applications range from consumer products such as cameras, camcorders, washing machines, and microwave ovens to industrial process control, medical instrumentation, decision-support systems, and portfolio selection.

To understand why use of fuzzy logic has grown, you must first understand what is meant by fuzzy logic. Fuzzy logic has two different meanings. In a narrow sense, fuzzy logic is a logical system, which is an extension of multivalve logic. However, in a wider sense fuzzy logic (FL) is almost synonymous with the theory of fuzzy sets, a theory which relates to classes of objects with unsharp boundaries in which membership is a matter of degree. In this perspective, fuzzy logic in its narrow sense is a branch of fl. Even in its more narrow definition, fuzzy logic differs both in concept and substance from traditional multivalve logical systems.

ISSN: 2278-4632
Vol-12 Issue-01 No.01: 2022



Leave the inference options in the lower left in their default positions for now. You've entered all the information you need for this particular GUI. Next define the membership functions associated with each of the variables.

To do this, open the Membership Function Editor. As a result, the requirement for energy transmission and distribution systems to compensate quickly is becoming increasingly crucial for this reason fuzzy logic controller is used to better results. The results of Fuzzy logic controller optimization are compared to those of a traditional controller and a GA-based PI controller, and better results are produced. The Fuzzy logic controller is performing dynamic response and reduced transient response. As shown in figure.9.

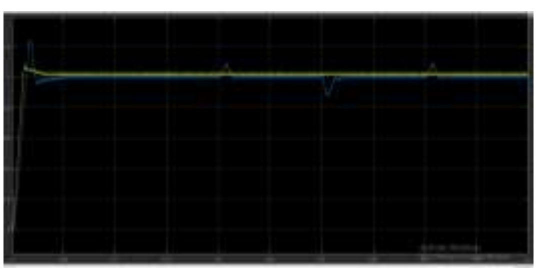


Fig. 9. Voltage profile at the end of the bus bar without STATCOM (a); voltage profile at the end of the bus bar for conventional GA controller, FLC optimized controller, with STATCOM (p.u.) (b).

III. CONCLUSIONS

The effects of a 2 MW induction generator-based wind production system and a 0.4 MW solar power generation system on the grid were explored in this study. It has been mentioned that STATCOM provides reactive power compensation for this hybrid system. The voltage profiles at the output of a solar PV-wind power system with a hybrid structure were investigated. STATCOM was used to investigate the system's voltage profiles in terms of capacitive and reactive operating states.

On this premise, this study found that power instability in large transmission systems may be reduced, as well as the fluctuations generated by the addition of renewable energy sources to the system. The effectiveness of the STATCOM adjusted with GA was improved when the results were compared. The voltage swell caused by the change in reactive power was overcome and a better dynamic response was achieved by obtaining the best values for PI controller gains.

Other optimization techniques will be used in future studies to determine which is the most effective. As a result, the need for energy transmission and distribution systems to compensate fast is growing, and fuzzy logic controllers are being employed to achieve better results. When the results of Fuzzy logic controller optimization are compared to those of a traditional controller and a GA-based PI controller, it is found that the Fuzzy logic controller optimization produces better results.

REFERENCES

[1] F. H. Gandoman, A. Ahmadi, A. M. Sharaf, P. Siano, J. Pou, B. Hredzak, V. G. Agelidis, “Review of FACTS technologies and applications for power quality in smart grids with renewable energy systems”, Renewable and Sustainable Energy Reviews, vol. 82, pp. 502–514, 2018. DOI: 10.1016/j.rser.2017.09.062.

[2] A. Mohanty, M. Viswavandya, D. K. Mishra, P. K. Ray, S. Pragyan, "Modelling & simulation of a PV based micro grid for enhanced stability", Energy Procedia, vol. 109, pp. 94–101, 2017. DOI: 10.1016/j.egypro.2017.03.060.

[3] H. Liao, S. Abdelrahman, J. V. Milanovic, "Zonal mitigation of power quality using FACTS devices for provision of differentiated quality of electricity supply in networks with renewable generation", IEEE Trans. Power Deliv., vol. 23, pp. 1975–85, 2017. DOI: 10.1109/TPWRD.2016.2585882.

[4] V. Kumar, A. S. Pandey, S. K. Sinha, "Grid integration and power quality issues of wind and solar energy system: A review", Int. Conf. Emerging Trends in Electrical Electronics & Sustainable Energy Systems (ICETEESES 2016), Sultanpur, India, 2016, pp. 71–80. DOI: 10.1109/ICETEESES.2016.7581355.

[5] D. Menniti, A. Pinnarelli, N. Sorrentino, "An hybrid PV-Wind supply system with D-Statcom interface for a water-lift station", IEEE Int. Symposium on Power Electronics, Electrical Drives, Automation and Motion, Pisa,Italy,2010.DOI:10.1109/SPEEDAM.2010.5545070.

[6] N. S. Kumar, J. Gokulakrishnan, "Impact of FACTS controllers on the stability of power systems connected with doubly fed induction generators", Electrical Power and Energy Systems, vol. 33, no. 5, pp. 1172–1184, 2011. DOI: 10.1016/j.ijepes.2011.01.031.

[7] S. Li, L. Xu, T.A. Haskew, "Control of VSC-based STATCOM using conventional and direct-current vector control strategies", Electrical Power and Energy Systems, vol. 45, no. 1, pp. 175–186, 2013. DOI: 10.1016/j.ijepes.2012.08.060.

[8] D. K. Yadav, T. S. Bhatti, "Voltage control through reactive power support for WECS based hybrid power system", Electrical Power and Energy Systems, vol. 62, pp. 507–518, 2014. DOI: 10.1016/j.ijepes.2014.04.067.

[9] M. K. Hossain, M. H. Ali, "Transient stability augmentation of PV/DFIG/SG-based hybrid power system by parallel-resonance bridge fault current limiter", Electric Power Systems Research, vol. 130, pp. 89–102, 2016. DOI: 10.1016/j.epsr.2015.08.016.

[10] P. Sharma, T. S. Bhatti, K. S. S. S. Ramakrishna, "Control of reactive power of autonomous wind-diesel hybrid power systems", Joint Int. Conf. Power Electronics, Drives and Energy Systems (PEDES 2010), New Delhi, India, 2010. DOI: [11] 10.1109/PEDES.2010.5712461.

[11]V. Sitthidet, N. Issarachai, K. Somyot, "Coordinated SVC and AVR for robust voltage control in a hybrid wind-diesel system", Energy Convers Management, vol. 51, no. 12, pp. 2383–93, 2010. DOI: 10.1016/j.enconman.2010.05.001.

[12] B. Abhik, V. Mukherjee, S. P. Ghoshal, "Modeling and seeker optimization based simulation for intelligent reactive power control of an isolated hybrid power system", Swarm and Evolution Computation, vol. 13, pp. 85–100, 2013. DOI: 10.1016/j.swevo.2013.05.003.

[13] A. A. Tanvir, A. Merabet, R. Beguenane, "Real-time control of active and reactive power for doubly fed induction generator (DFIG)-based wind energy conversion system", Energies, vol. 8, no. 9, pp. 10389– 10408, 2015. DOI: 10.3390/en80910389.

ISSN: 2278-4632
Vol-12 Issue-01 No.01: 2022

[14] S. B. Birinc, “Dynamic modeling and comparison of variable speed wind power plants”, M.S. thesis, Yildiz Technical University, Institute of Science, 2008.

[15] G. Abad, J. Lopez, M. A. Rodriguez, L. Marroyo, G. Iwanski, “Dynamic modeling of the doubly fed induction machine”, in Doubly Fed Induction Machine, Hoboken, NJ, USA: John Wiley & Sons, Inc., 2011, pp. 209–239. DOI: 10.1002/9781118104965.ch4.

[16] M. A. Ozcelik, A. S. Yilmaz, S. Kucuk, M. Bayrak, “Efficiency in Centralized DC systems compared with distributed DC systems in photovoltaic energy conversion”, Elektronika Ir Elektrotechnika, vol. 21, no. 6, pp. 51–56, 2015. DOI: 10.5755/j01.eee.21.6.13761.

[17] M. Karatas, “Control of static synchronous compensator with pid controller”, M.S. thesis, Electrical and Electronics Engineering, Malatya, Turkey, 2011.