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# **Performance Evolution of Hybrid Energy Generation and Static Var Compensation for Stability Load Analysis Using Multi-Objective Partial Swarm Optimization Algorithm**

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### **ABSTRACT:**

A wind-solar hybrid power generation system consisting of photovoltaic (PV) modules and permanent magnet synchronous generator (PMSG) based wind generation controlled by Multi-Objective Partial Swarm Optimization (MOPSO) technique for both converter and inverter for the stability of a grid-connected system. The proposed method improves the power quality without voltage sag and swell. Multi-Objective Partial Swarm Optimization (MOPSO) algorithm was developed to find out the best operating point of a Static VAR Compensator (SVC) for the enhancement of power compensation. Reduces the voltage distortion caused by harmonics. Stabilizes the voltage and diminish the voltage fluctuation and flicker. The application SVC is used for multi-objective power flow that minimizes generation cost, decreasing the voltage deviation, reducing of voltage deviation stability L-Index, minimizing of total power loss and minimizing the installation cost of SVC device by including some of the constraints. Overall the multi-objective optimization will be used for future load flow analysis and effective planning in the power system.

**KEYWORD:** Harmonics reduction, Multi-Objective Partial Swarm Optimization Algorithm, Static VAR Compensator, Converter, Inverter.

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## I. INTRODUCTION

A hybrid solar-wind system consists of Photovoltaic array, wind turbine, DC bus, AC bus, inverter, controller and cables. The PV array and wind turbine work together to compensate for the load demand. Energy sources when (solar-wind) are abundant, the power generated from the solar, in the day time it will continue to charge until the battery is fully charged. On different the when energy sources are poor, the battery will deliver energy to support the PV array and wind turbine to cover the load conditions until the storage is consumed. The hybrid solar-wind system modeling is mainly subordinate on the performance of individual components. In order to predict the system performance, both sources of power generation should be modeled separately and will be combined to meet the demanding reliability. If the power output forecast from these individual sources is accurate enough, the resultant combination will deliver power effectively. A hybrid system could be designed to work either in isolated mode or in grid-connected mode, through power electronic interface. To ensure the power system security, the OPRPP problem is associated with the contingency analysis problem. The contingency analysis, which is a well-known function in power system planning and operation, is used later to predict the contingencies which make system violated and rank the contingencies according to their relative severity.

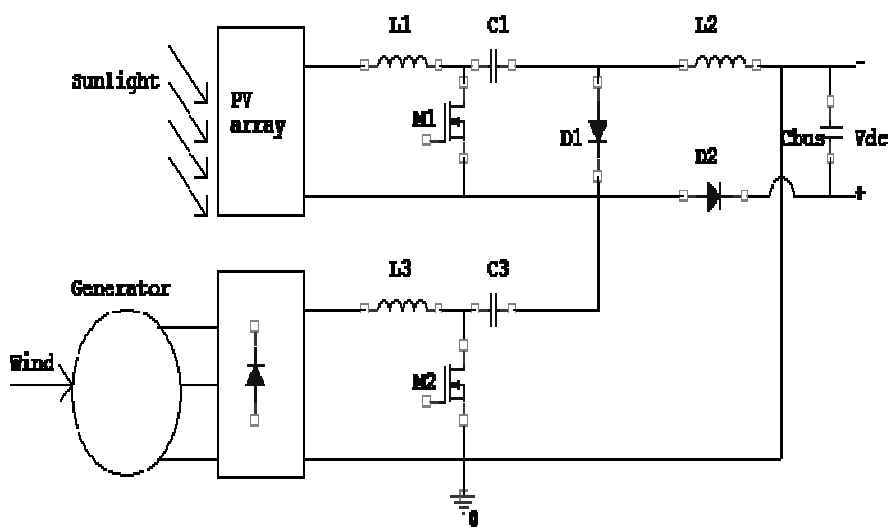


Figure 1: Hybrid Wind and Solar Energy System

An outage of a transmission line, capacitor bank or transformer may lead to overloads in other branches and sudden system voltage rise or drop. The Hybrid multi Particle Swarm Optimization and Gravitational Search have been used for solving the reactive power planning using SVC's device. Various critical situations are simulated to prove the effectiveness of the proposed algorithm and to ensure the viability of the power system in contingency scenarios. The locations of the SVC's devices considering voltage security are determined using three different stability indexes namely, Fast Voltage Stability Index (FVSI), Line stability index and Line Stability Factor. The

simulation outcome shows the high performance of MOPSO algorithm on minimizing the transmission power losses and on improving the real power and annual cost savings. The analyses of the results are very promising since the main objectives of the proposed technique is reduced the power loss, and harmonics are proposed, controller. Hybrid power systems are a rapidly growing area of research. Not only domestic, commercial and industrial loads are studied to be switched to these systems but implemented effectively in automobiles. Renewable energy resources are solar power, wind power, tidal power, geothermal power, wave power, and biomass. They are persistent, naturally renewing themselves and environment-friendly. This is why they are called green energy resources. Unrenewable conventional energy resources such as oil, coal, gas, etc. decrease slowly with time. The main feature renewable energy systems are to combine two or can address efficiency, reliability, emissions and economic limitations of single renewable energy source. The methodology aims to find the configuration, among a set of system components, which meets the desired system reliability requirements with the lowest value of costs.

## **II. LITERATURE REVIEW**

The proposed approach is compared to previous methods using experimental measurements. Bilal Khan<sup>1</sup> their operation is accompanied, with fluctuating wind speeds, transients, and abrupt power variations. The voltage at the point of common coupling with the grid, violates stable voltages limits, even during low speeds. In this paper static compensators (STATCOM), and static VAR compensators (SVC) has been used to improve the transient stability of wind farms based on fixed speed wind turbines with adjustable rotor resistance. Li Wang<sup>2</sup> this model presents the stability improvement of a multi machine power system connected with a large-scale hybrid wind-photovoltaic (PV) farm using an energy-storage unit based on supercapacitor (SC). The operating characteristics of the hybrid wind-PV farm are simulated by an equivalent aggregated 300-MW wind-turbine generator (WTG) based on permanent-magnet synchronous generator. Yanzhang Liu<sup>3</sup> the voltage and reactive power control strategy uses the grid-connected inverters and static VAR compensation (SVC) device as flexible and controllable source of reactive power to regulate the voltage and reactive power of large-scale PV power plants.

Avudai Lakshmi<sup>4</sup> These voltage fluctuations can be eliminated with the help of advanced reactive power compensation devices such as SVC (Static VAR Compensator), STATCOM (Static Synchronous Compensator) and DVR (Dynamic Voltage Restorer). In this model, STATCOM is used as a compensating device. STATCOM is a static synchronous generator operated as a parallel connection static reactive compensator. Yeonho Ok<sup>5</sup> the phenomenon of voltage rise when the renewable energy power plants are connected to the distribution grid is analyzed. For analysis of

voltage rise phenomenon, the actual operation data with some kinds of renewable energy power plants such as small hydro power plant, solar power plant and wind power plant are gathered firstly. Hassan Zahboune<sup>6</sup> the system of study contains a wind turbine (asynchronous generator) connected to an AC 1 DC converter, a static VAR compensator (SVC) represents a variable capacity and an LC filter to supply a resistive load. Yousef Mahmoud<sup>7</sup> an accurate model is essential when designing photovoltaic (PV) systems. PV models rely on a set of transcendental nonlinear equations which add to the model complexity. This letter proposes a simple and easy-to-model approach for implementation in simulations of PV systems.

Joanne Hui<sup>8</sup> this model presents a new system configuration of the front-end rectifier stage for a hybrid wind/photovoltaic energy system. This configuration allows the two sources to supply the load separately or simultaneously depending on the availability of the energy sources. The inherent nature of this Cuk-SEPIC fused converter, additional input filters are not necessary to filter out high frequency harmonics. Harmonic content is detrimental for the generator lifespan, heating issues, and efficiency. Bharanikumar<sup>9</sup> a Wind Generator System that employs a boost chopper and a permanent magnet synchronous generator is studied. By replacing the main circuit of generator and boost chopper with the equivalent circuit, the power and DC output voltage are obtained as a function of duty ratio of the boost chopper and generator rotational frequency. Dumitru Cristian Drago<sup>10</sup> Virtually all regions of the world have renewable resources of one type or another. By this point of view studies on renewable energies focus more and more attention. The present model intends to present different mathematical models related to different types of renewable energy sources such as: solar energy and wind energy. It is also presented the validation and adaptation of such models to hybrid systems working in geographical and meteorological conditions.

### **III. PROPOSED SYSTEM**

The proposed method presents, a wind-solar hybrid power generator system consisting of photovoltaic (PV) modules controlled by Multi-Objective Partial Swarm Optimization (MOPSO) method and connected to a DC-DC boost converter, a grid-connected wind turbine coupled with a permanent magnet synchronous generator (PMSG) and connected to a back-to-back converter and also a bidirectional DC-DC converter, and finally an energy storage module (batteries) connected to a bidirectional DC-DC converter has been modeled, implemented and discussed in this work to achieve an efficient and cost-effective system configuration so that renewable energy power sources could improve the life of people in both urban and remote residential areas. Additionally, a device Static VAR Compensators (SVCs) have been used to improve both the power angle stability of

generators and the voltage behavior at the SVC location. SVC address unbalanced voltage problems in distribution, sub-transmission and transmission networks.

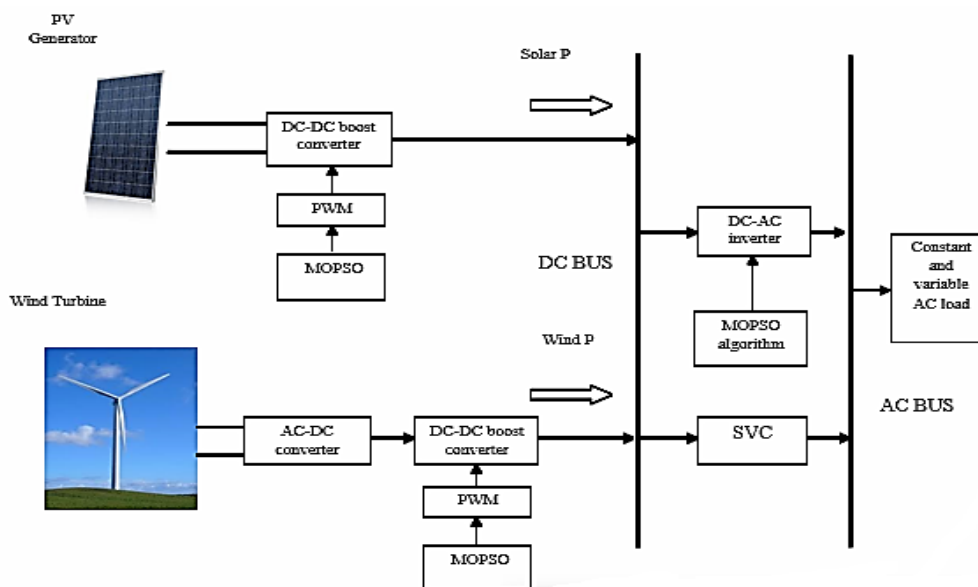
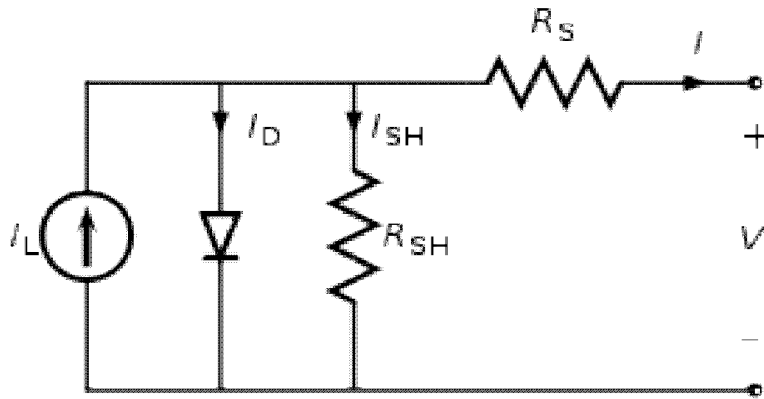


Figure 2: Block Diagram

The word photovoltaic combines two terms photo means light and voltaic means voltage. Photovoltaic energy is obtained from sunlight in the form of solar energy. Wind power is the management of kinetic flow through wind turbines to kinetic power generators for electric power. Wind energy, as an option to burning fossil fuels, is abundant, renewable, generally distributed, clean, creates no harmful gas emissions during operation, consumes no water, and uses little land. Both the PV and wind system can be output improved by using DC-DC boost converters. The dc bus voltage controllers are designed based on the assumption that the dc bus is purely capacitive. Therefore, a purely capacitive dc bus with capacitance equal to the total converter dc link capacitance is analyzed. Multi-Objective Partial Swarm Optimization (MOPSO) algorithm is used to reduce harmonics distortion and noises. Finally, the improved voltage has been inverted and given to the ac grid.

### 3.1 Solar Power

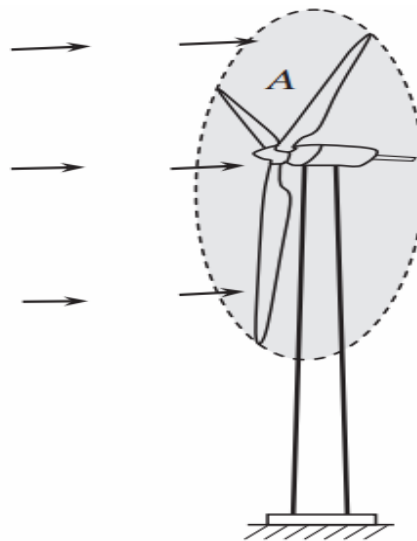
The word photovoltaic combines two terms photo means light and voltaic means voltage. Photovoltaic energy is obtained from sunlight in the form of solar energy. The sunlight is made to be focused on solar panels which have the ability to convert the solar energy to electrical energy. The conversion of solar energy to electrical energy is done by solar cells of the solar panel. A solar panel is a compilation of solar photovoltaic modules electrically connected and attached on a supporting arrangement. A photovoltaic module is a packaged, combined arrangement of solar cells.



**Figure 3: Equivalent Circuit of Solar Cell**

The solar panel can be employed as a segment of a larger photovoltaic system to generate and generate electricity in commercial and residential applications. Its DC output power rates each module under standard test conditions (STC), and typically ranges from 100 to 320 watts. The efficiency of a module limits the area of a module given the same rated output efficient module will have twice the area of a dynamic module. A single solar module can provide only a limited amount of power; most installations contain multiple modules. A photovoltaic system typically includes a panel or an array of solar modules, an inverter, and sometimes a battery and/or solar tracker and interconnection wiring.

### 3.2 Wind Energy



**Figure 4: Wind Turbine**

Wind turbines correspondingly generate electrical power as all other generation technologies. The only variation is in the source of the mechanical power satisfied with the electrical generator. Wind energy is a special form of kinetic energy in the air as it flows. Wind energy can be either converted into electrical energy by power converting machines or directly used for pumping water, sailing ships, or grinding grain. Kinetic energy exists whenever an object of a given mass is in motion with a translational or rotational speed. Wind power density is a comprehensive index in evaluating

the wind resource at a particular site. It is the available wind power in airflow through a perpendicular cross-sectional unit area in a unit time period.

### 3.3 DC to DC Boost Converter:

The DC-DC converters are used to convert the unregulated dc input to a controlled dc output at the desired voltage level. They generally accomplish the conversion by employing a dc voltage across an inductor or transformer for a duration of time (usually in the 20 kHz to 5 MHz range) which begins current to passing through it and store energy magnetically, then switching this voltage off and producing the stored energy to be assigned to the voltage output in a controlled manner.

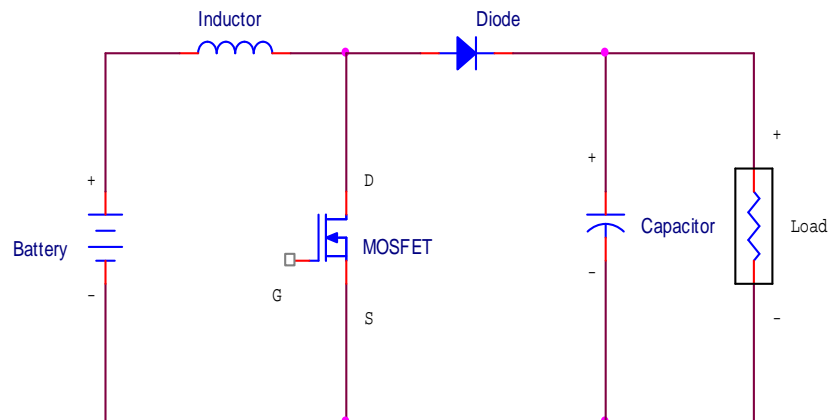


Figure 5: Boost Converter Circuit Diagram

The output voltage is controlled by regulating the ratio of on/off time. This is achieved using switched mode circuits whose elements dissipate negligible power. Pulse width modulation provides control and regulation of the total output voltage. It is considered as the response of the power supply. Thus it will change the overall execution of the power supply system.

### 3.4 AC to DC Converter

The AC to DC converts the AC voltage to pulsating DC, which is smoothed by the smoothing circuit. The output voltage of the Energy supply is assumed to remain constant against variations in the load current or variations in input voltage.

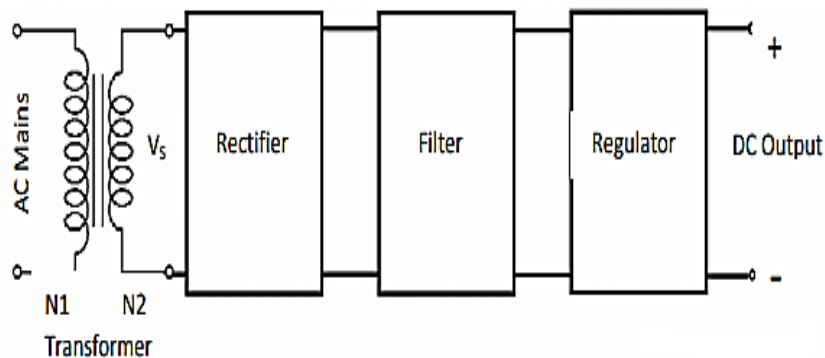


Figure 6: AC to DC Converter

This is performed by using a suitable voltage regulator. This property of diode presents it an essential component of DC power supplies which are used to power electronic systems and circuits. The transformer is utilized to step down the AC mains voltage. The transformer also presents electrical isolation to the electronic system from AC mains.

### 3.5 DC to AC Inverter:

An inverter is an electronic device or that changes direct current (DC) to alternating current (AC). An inverter transforms the DC voltage to an AC voltage. In most cases, the input DC voltage is usually lower while the output AC is equal to the grid supply voltage of either 120 volts, or 240 Volts depending on the country. The inverter may be built as standalone equipment for applications such as solar power, or to work as backup power supply from batteries which are charged separately. There are several types of inverters based on the shape of the switching waveform. These have varying circuit configurations, efficiencies, advantages, and disadvantages.

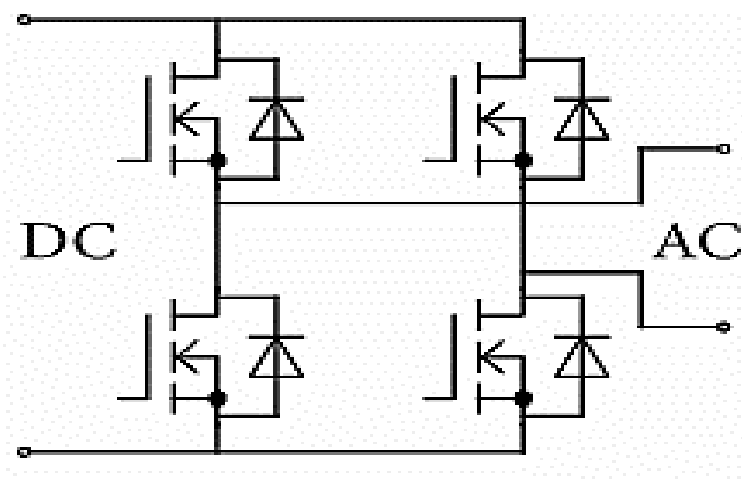


Figure 7: Simple H Bridge Inverter

An inverter provides an AC voltage from dc power sources and is useful in power electronics and electrical equipment rated at the ac mains voltage. In addition, they are widely used in the switched mode power supplies inverting stages. Inverters are used to eliminate the bulky transformer required in case of conventional multi-phase inverters, clamping diodes required in case of diode-clamped inverters and flying capacitors required in case of flying capacitor inverters. But these require a large number of isolated voltages to supply each cell.

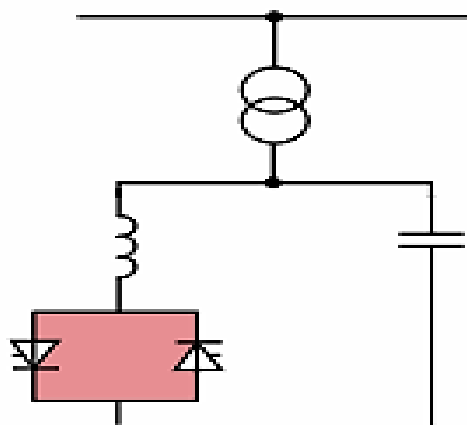
### 3.6 Static VAR Compensator:

The static compensators are used in a power system to increase the power transmission capacity with a given network, from the generators to the loads. Since static compensators cannot generate or absorb real power, the power transmission of the system is affected indirectly by voltage control. That is, the reactive output power (capacitive or inductive) of compensator is varied to



control the voltage at given terminals of the transmission network so as to maintain the desired power flow under possible system disturbances and contingencies. SVCs are part of the transmission system device family, regulating voltage and stabilizing the system. Unlike a synchronous condenser which is a rotating electrical machine, a "static" VAR compensator has no significant moving parts (other than internal switchgear). Prior to the invention of the SVC, power factor compensation was the preserve of large rotating machines such as synchronous condensers or switched capacitor banks.

The SVC is an automated impedance matching device, designed to bring the system closer to unity power factor. SVCs are used in two main situations: Connected to the power system, to regulate the transmission voltage Connected near large industrial loads, to improve power quality ("Industrial SVC"). In transmission applications, the SVC is used to regulate the grid voltage. If the power system's reactive load is capacitive (leading), the SVC will use thyristor controlled reactors to consume vars from the system, lowering the system voltage. Under inductive (lagging) conditions, the capacitor banks are automatically switched in, thus providing a higher system voltage. By connecting the thyristor controlled reactor, which is continuously variable, along with a capacitor bank step, the net result is continuously-variable leading or lagging power. SVC is the preferred mechanism for dynamic reactive power support in high voltage transmission grids. To its essential capability for high-speed, cycle-by-cycle control of VAR, it will counteract the often hazardous voltage depressions that develop in conjunction with faults in the grid. These highly dynamic events, where the ever-increasing use of induction motors (like those in various units and wind power turbine-generators) stresses the grid, will need an SVC to maintain the grid voltage and safeguard the fault ride-through capability.



**Figure 8: Static VAR Compensator**

An SVC can increase power system transmission and distribution performance in a number of ways. Installing a static VAR compensator at one or more suitable points in the network can increase transfer capability and diminish losses while sustaining a balance voltage profile under

different grid conditions. The dynamic stability of the grid can also be enhanced, and active power oscillations mitigated.

Often the SVC slope setting must be represented to properly simulate system performance. Coordination and interaction with other WCs and slower-acting voltage control equipment are studied. Power flow simulation is the primary tool for determining appropriate slope settings. Representation of the slope is essential in the case of weak systems. Because SVCs are sited at critical locations in the network, and because of the regulation of transmission (high side) voltage, representation of SVC slope is usually more important than representation of generator slope. For tertiary-connected SVCs, the transformer representation is required.

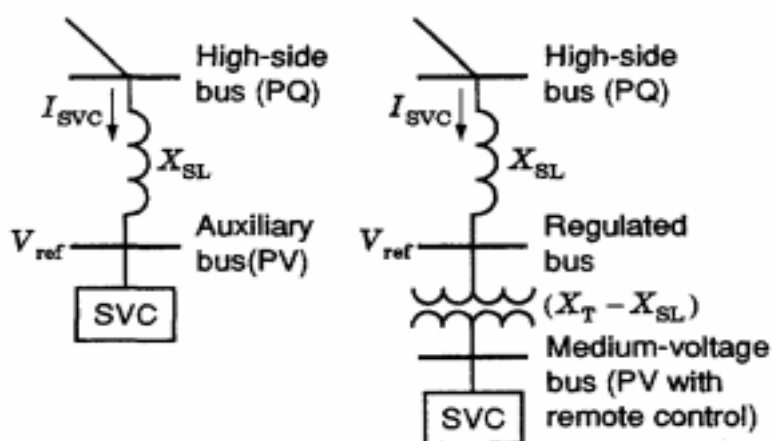


Figure 9: SVC models with slope representation using conventional power flow W busses.

The real power flow through the transformer as well as the SVC voltage regulation must be modelled correctly. If the SVC coupling transformer is explicitly represented, the SVC model (steady state or dynamic) must be adjusted so the correct range of reactive power is delivered to the high voltage bus. Most models and data sets presently used are based on susceptance current active power limits at the high voltage bus.

### 3.7 MOPSO Controller:

In this work, Multi-Objective Partial Swarm Optimization (MOPSO) algorithm was developed to find out the best operating point of a Static VAR Compensator (SVC) for the enhancement of power compensation. This technique is used to reduce harmonics distortion and noises. Finally, the improved voltage has been inverted and given to the ac grid. The features of the proposed topology are the inherent nature of these two converters eliminates the need for separate input filters for PFC it can support step up/down operations for each renewable source (can support wide ranges of PV and wind input) realized for each source individual and simultaneous operation is supported.

#### IV. CIRCUIT DIAGRAM:

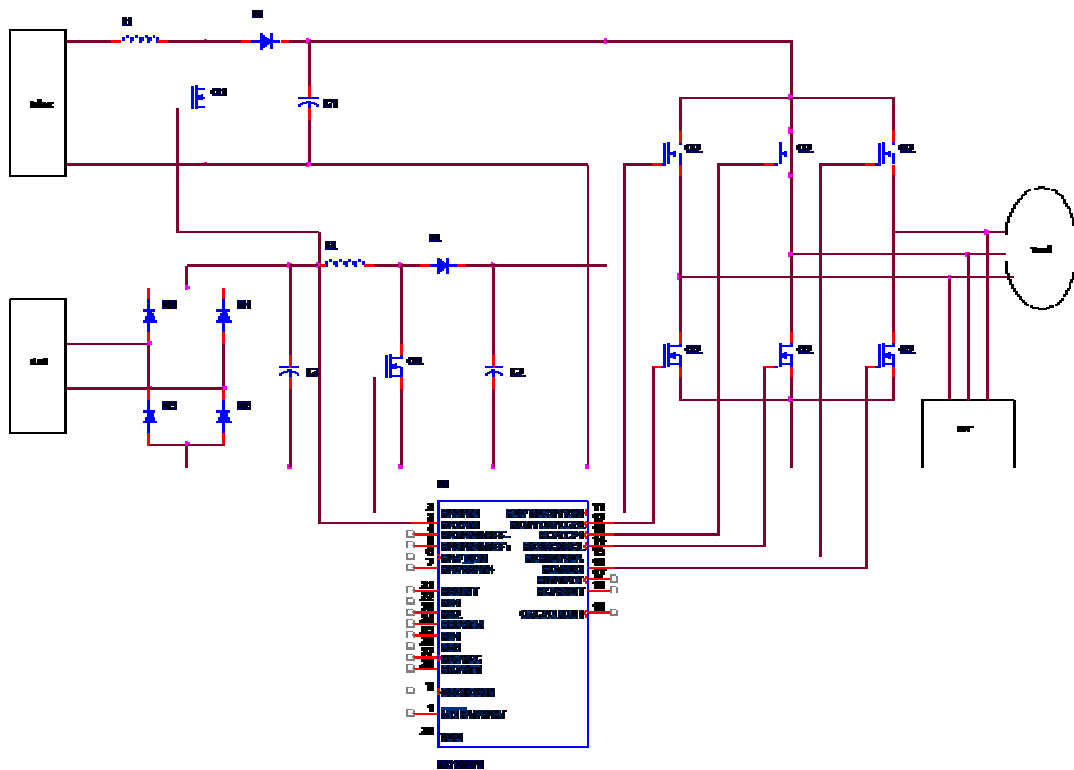


Figure 10: Circuit Diagram

- In this system, the solar and wind power is used to the system but the output power is not stable, so in this system implement the Multi-Objective Partial Swarm Optimization Algorithm (MOPSO) technique and get the better performance of the system.
- The controller is provided switching pulse of the converter and inverter switches. And also the Static VAR Compensator is used to the output side of the system if any unbalance condition occurs in the load side the SVC is compensated the output voltage. And also this model reduces the total harmonics distortion and increase efficiency.

#### 4.1 Hardware Model of Proposed System



**Figure 11: Hardware Model for the Proposed System.**

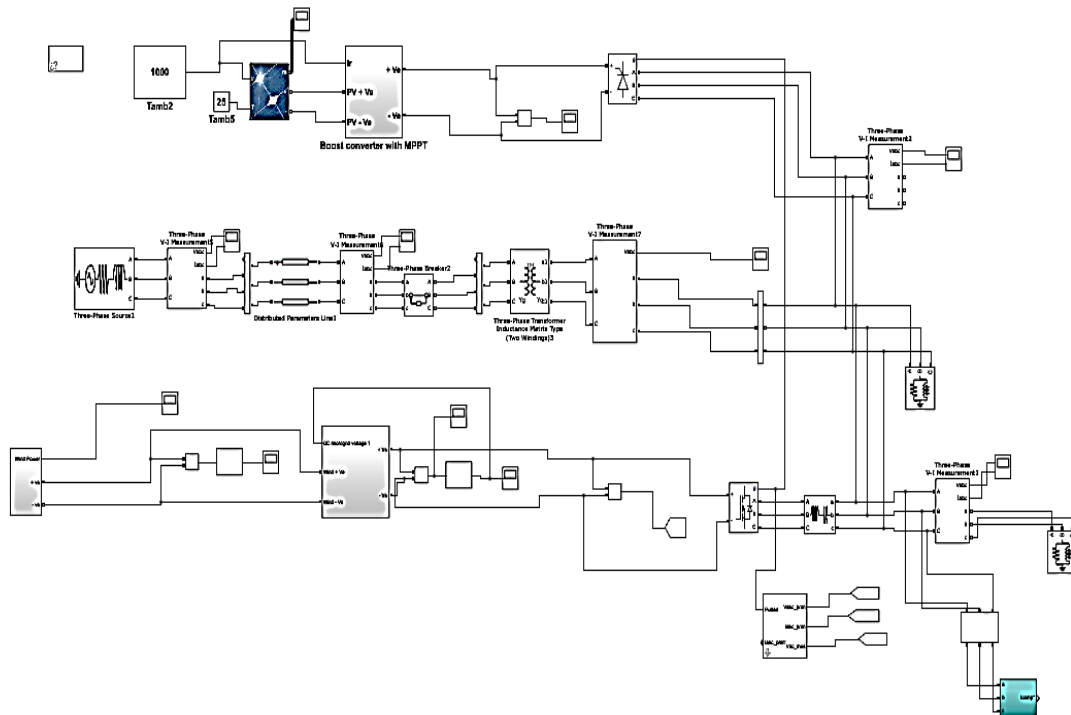
- **Figure 11** represents the proposed Hardware for the hybrid energy generation and static compensation for stability load analysis. The model consists of solar power, DC-DC converter, Boost converter, Inverter, Solar Panel, PIC controller and current transformer and load system.
- At the initial stage of operation the battery is connected to the solar panel for charging whenever the solar is available, the wind system is converted AC to DC and directly connected DC Bus.
- The DC Bus is connected to the connected to the inverter. The inverter is Converted DC-AC voltage will give to the step up transformer it increases the voltage up to (12-230)V it access the Load system
- If additional load is added into the circuit SVC is provide feedback to the PIC16f877A controller. The controller accelerate the PWM to the converter for proper voltage stabilization. Hence the load hybrid power Stabilization will access the energy sources into load condition.

#### 4.2 Hardware Tabulation Output

Hardware	Specification	Input Ranges	Output Ranges
Solar	Input power	11v	13v
Battery	Input power	12V	1.5A
Microcontroller	PIC (16f877a)	5V DC	5V DC
Rectifier	Input power	12V AC	12V DC
Inverter	Output power	12V DC	12V AC
Boost converter	Regulating power	12V	0-25v
Transformer	step-up	24VAC	230VAC
Load	Load	230V	2A
Load	Load	230V	3A

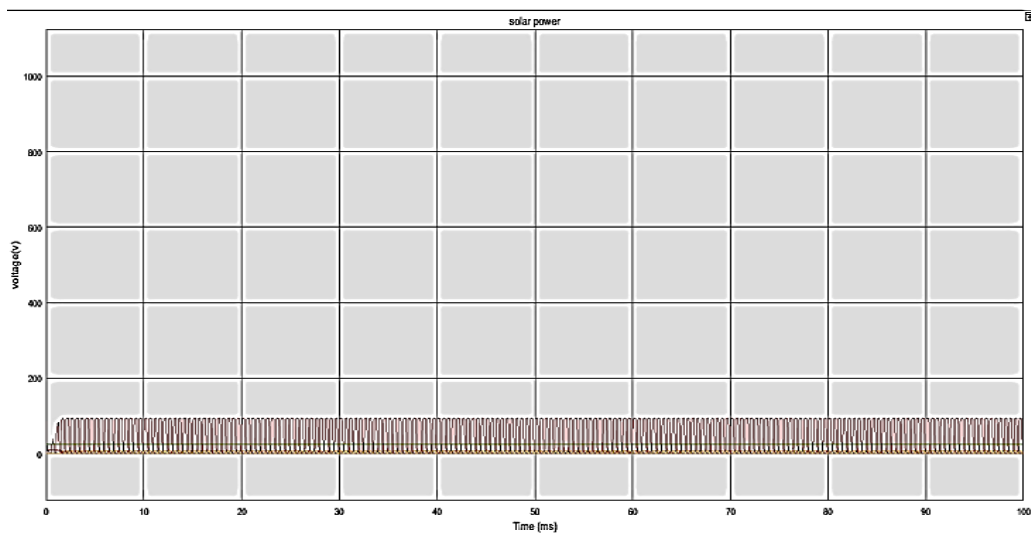
#### V. RESULT AND DISCUSSION:

The present modeling approach of a Mat lab-based toolbox for developing and testing the Hybrid Energy Generation using Multi-Objective Partial Swarm Optimization. Algorithm (MOPSO) under various operational conditions. The proposed model is developed in MATLAB environment.



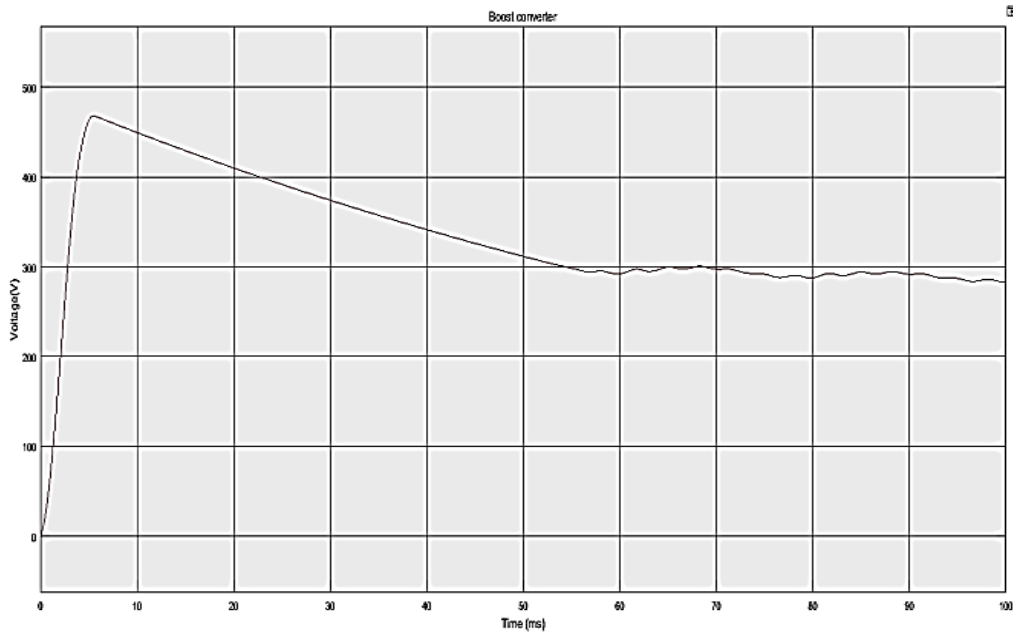
**Figure 12: Simulation for the Proposed Method**

The above figure 12 shows the overall simulation of the proposed method. The simulation diagram which represents power flow between the generating to load. The Power has some of the variations in the load side. Its need to be optimized by the Multi-Objective Partial Swarm Optimization. Algorithm proposed algorithm method.



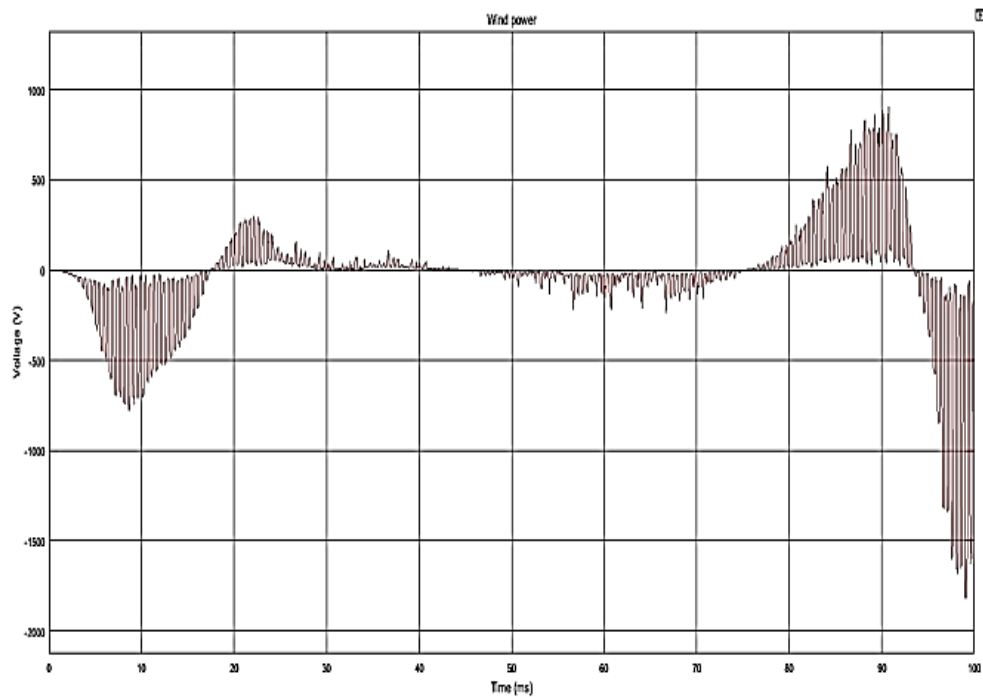
**Figure 13: Solar Output Waveform**

The above figure 13 shows PV (solar) output. PV generated DC voltage up to 100 V. This output DC voltage is applied to boost converter.



**Figure 14: Solar Boost Converter Output Waveform**

The above figure 14 shows the Boost converter output waveform. PV generated DC voltage is low, so the boost converter increases the PV output voltage up to 300 Volts.



**Figure 15: Wind Turbine Output Waveform**

The above figure 15 shows the wind turbine output waveform. Wind generates AC voltage, and it applied to AC to DC converter and converts AC to DC voltage.

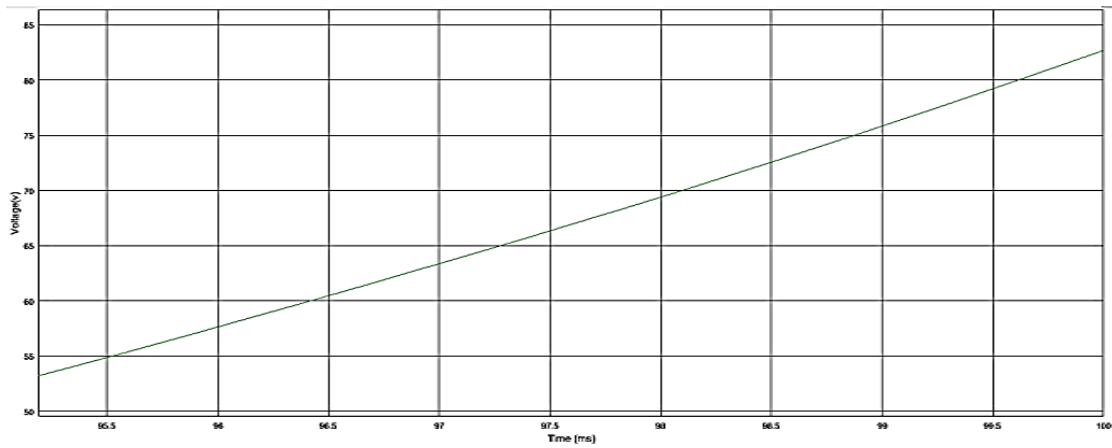


Figure 16: Wind Boost Converter Output Waveform

The above figure 16 shows the boosted voltage of the wind turbine output waveform. This output voltage is increased by DC to DC boost converter circuit.

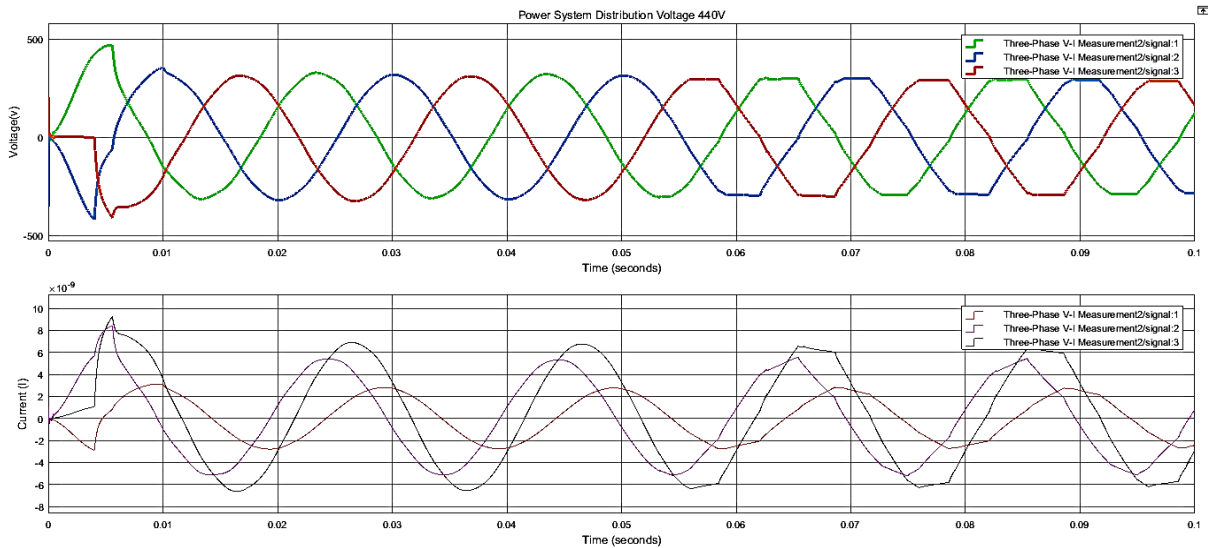


Figure 17: Overall Simulation Output Waveform

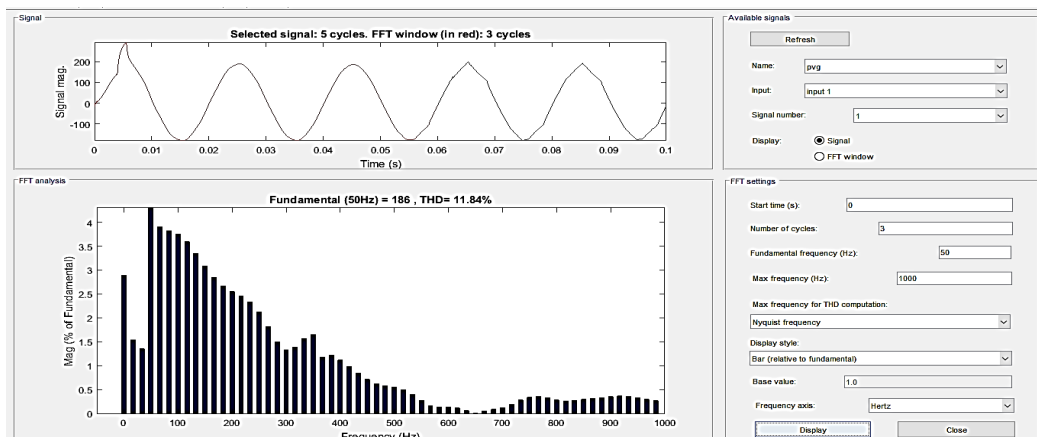


Figure 18: THD Analysis

The THD analysis of the proposed system and it is essential to monitor the output voltage, in this system Total Harmonics Distortion is 11.84%.



### **5.1 Scope:**

- Less number of harmonics and Very high reliability.
- Long term sustainability and also High energy output.
- Distributed generation applications
- Constant speed and variable speed wind energy conversion system

## **VI. CONCLUSION:**

In this work, a new PV-wind turbine hybrid power system was designed, modeled and implemented using the MATLAB/Simulink software package for smart grid applications. As the available power from the proposed PV system is highly dependent on solar radiation, to overcome this deficiency, the PV system was integrated with the wind turbine system. The dynamic behavior of the proposed model was examined under different operating conditions. Solar irradiance, and wind speed data were gathered for a grid-connected wind-solar power system installed in a residential area. The proposed algorithm gives better output results over then existing algorithm. The developed system and its control strategy exhibited excellent performance. The proposed model offers a proper tool for smart grid performance optimization.

## **VII. REFERENCES**

1. Bilal Khan, Mahmoud Kassas, "FSIG-Based Wind Power Plant Transient Stability Margin Improvement, a STATCOM/SVC Comparison" in IEEE Texas Power and Energy Conference, 2019.
2. Li Wang, Quang-Son VO, Anton V. Prokhorov, "Stability Improvement of A Multi machine Power System Connected With A Large Scale Hybrid Wind-Photovoltaic Farm Using A Supercapacitor" IEEE Transactions on Industry Applications, 2018; 0093-9994.
3. Yanzhang Liu, Lei Zhang, "Study on Control Characteristic of Grid-connected Solar Photovoltaic Plant Based on Simulation" in international conference on Electric Utility Deregulation and Restructuring and Power Technologies, 2015.
4. B. Avudai Lakshmi, R. Karpagam, "Resonant Controller Based STATCOM Used in Wind Farms to Mitigate Power Quality Issues" in International Conference on Electrical, Computer and Communication Technologies, 2015.
5. Yeonho Ok, Jaeho Choi, "Analysis of Voltage Rise Phenomenon in Distribution Lines Associated with Grid-Connected Renewable Energy System" in International Conference on Power Electronics, 2015.

6. Hassan Zahboune, SmailZouggar, "The Voltage Regulation of Asynchronous Wind Turbine Using a SVC" in International Renewable and Sustainable Energy Conference, 2014; 17-19,.
7. Mahmoud Et Al.," A Simple Approach to Modeling and Simulation of Photovoltaic Modules," IEEE Transactions on Sustainable Energy, January 2012; 3(1).
8. A. Bakhshai Et Al., "A Hybrid Wind-Solar Energy System: A New Rectifier Stage Topology" IEEE Magazine, July 2010.
9. R. Bharanikumar And A. Nirmal Kumar, "Analysis of Wind Turbine Driven Pm Generator with Power Converters" International Journal of Computer and Electrical Engineering, August 2010; 2(4)
10. D. C. Drago and G. Adrian, "Modeling of Renewable Hybrid Energy Sources" Scientific Bulletin of the Petru Maior University of Tirgu Mures, 2009; 6
11. J. Hui, "An Adaptive Control Algorithm for Maximum Power Point Tracking for Wind Energy Conversion Systems "Department Of Electrical And Computer Engineering, Queen's University, December 2008.
12. S. Jain and V. Agarwal, "An Integrated Hybrid Power Supply for Distributed Generation Applications Fed By Nonconventional Energy Sources" IEEE Transactions on Energy Conversion, June 2008; 22(2)
13. Kim Et Al., "Dynamic Modeling and Control of A Grid-Connected Hybrid Generation System with Versatile Power Transfer" IEEE Transactions on Industrial Electronics, April 2008; 55(4).
14. Chen Et Al., "Multi-Input Inverter for Grid-Connected Hybrid Pv/Wind Power System" IEEE Transactions on Power Electronics, May 2007; 22.
15. R. Billinton and R. Karki, "Capacity Expansion of Small Isolated Power Systems Using PV and Wind Energy" IEEE Transactions on Power Systems, November 2001; 1