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AUTOMATICS

MODELLING AND ANALYSIS OF HYBRID POWER STATION

Atanas Chervenkov, Atanas Yanev, Todorka Chervevnkova

Abstract: *The power station with renewable generating sources is considered. It consist of Photovoltaic plant and Wind-generator. A model of hybrid power station in MATLAB is created. Simulations of the power station operation have been carried out in different modes. The performance of hybrid power station is analysed. The harmonic composition of the generated AC voltage with an industrial frequency is investigated.*
Keywords: *analysis, modelling, hybrid power station, photovoltaic plant, wind-generator, MATLAB, harmonics.*

1. INTRODUCTION

A convenient, cost-effective and reliable power supply is an essential factor in the development of any area. To overcome all the disadvantages possessed by the conventional method of electricity generation and transmission distributed energy generation is being preferred and promoted. There are several ways by which electricity can be generated locally using renewable sources such as solar, wind, biogas, etc. [2]. At present, standalone solar photovoltaic and wind systems have been promoted around the globe on a comparatively larger scale [1]. These independent systems cannot provide continuous source of energy, as they are seasonal. Therefore, suitable energy storage systems will be required for these systems in order to satisfy the power demands. Usually storage system is expensive and the size has to be reduced to a minimum possible for the renewable energy system to be cost effective. The cost effective solution would be hybrid power systems which can reduce energy storage requirements. In this paprer a standalone hybrid power station with suistable renewable energy sources - solar photovoltaic and wind generators is considered.

2. DESCRIPTION OF THE HYBRID POWER STATION

The hybrid power station is consist two reneable sources of small power (10kW) PV plant and wind generator. The power station is not connected to a distribution grid and power system supplied the AC loads. To store the generated electricity in the case of an absence of generating power, a rechargeable battery is used. The transformation of the produced energy with DC-AC inverter is carried out. To restrict and optimize charging and battery discharge processes a controller is used.
Figure 1 show the configuration structure for hybrid system based solar and wind energy sources.

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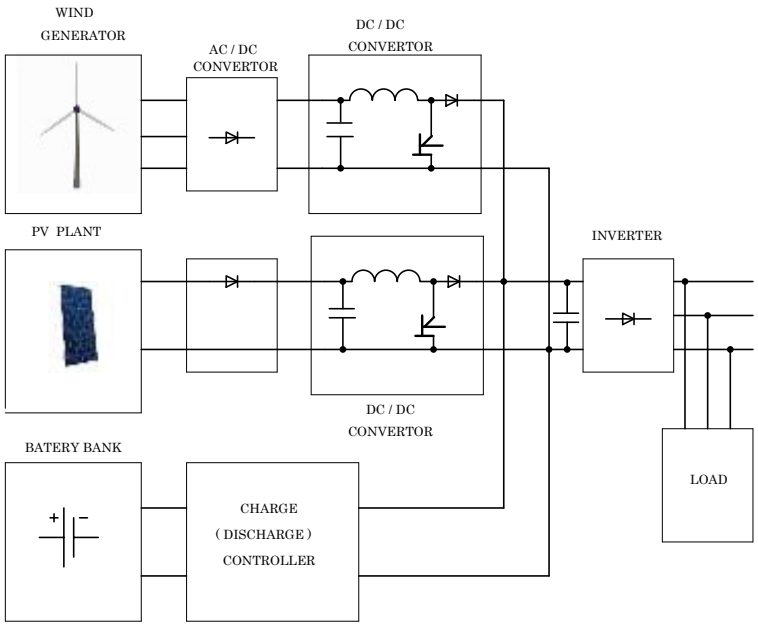

Fig.1. Configuration of Hybrid Energy System.

The hybrid power generation system using wind and solar power includes the following subsystem: solar array, wind turbine, charge controller, battery bank and inverter.

The location of the hybrid power station and climatic conditions is shown in Figure 2 and Figure 3, respectively.

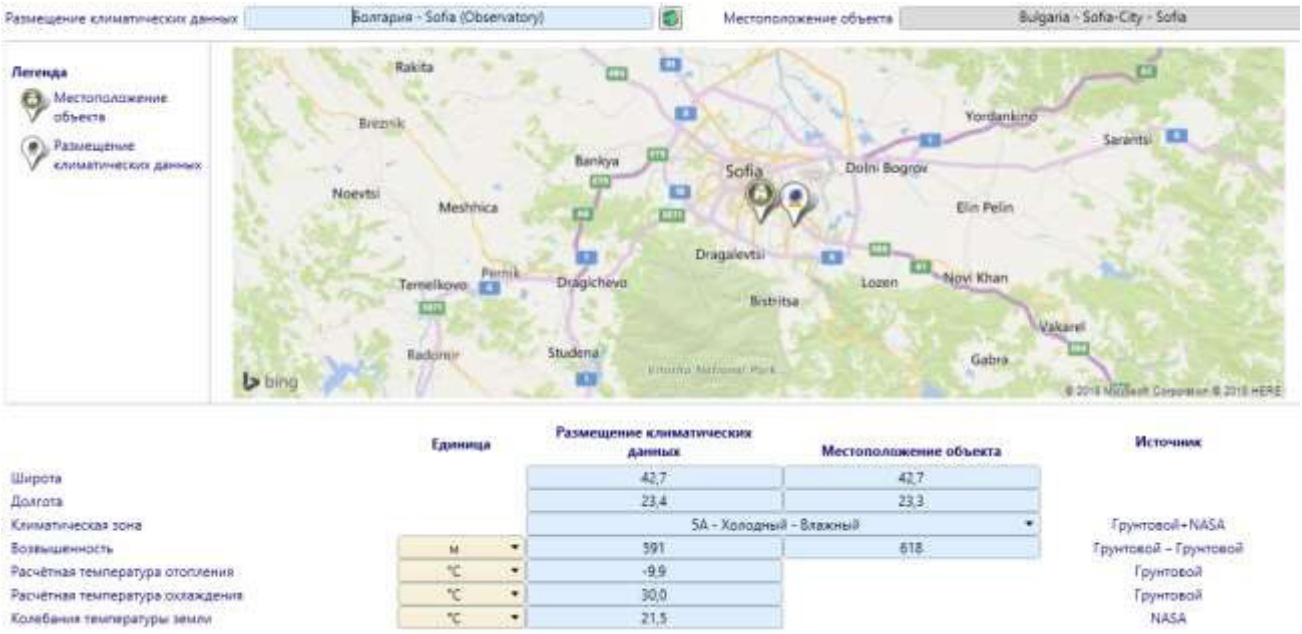

Fig.2. Location of the hybrid power station

1. PV plant

It consists of an arrangement of several components, including solar panels. Solar panels are used to convert solar radiation to the electrical energy. Solar panel is a group of a several monocrystalline silicon(mono-Si) modules electrically connected in series parallel combination to generate the required current and voltage. The electrical power of PV plant is 10 kW, its efficiency is 15.75% and the area of the solar collectors is 63.5 square meters. The generated electricity per year is 10 MWh [3].

Месяц	Температура воздуха °C	Относительная влажность %	Осадки мм	Дневная сумма солнечной радиации - горизонтальная кВтч/м²/день	Атмосферное давление кПа	Скорость ветра м/с	Температура земли °C	Градусо-дни отопительного сезона 18 °C °C-д	Градусо-дни с отрицательной температурой 10 °C °C-д
Январь	-1,1	79,1%	64,86	1,26	95,1	2,2	-2,3	592	0
Февраль	0,5	72,6%	52,64	2,05	95,0	2,6	-0,5	490	0
Март	5,0	66,5%	52,87	2,97	94,8	2,7	4,6	403	0
Апрель	10,2	65,4%	62,85	3,87	94,6	2,7	10,5	234	6
Май	14,9	67,8%	70,84	4,69	94,8	2,4	16,3	96	152
Июнь	18,3	67,5%	70,11	5,38	94,8	2,3	20,7	0	249
Июль	20,8	63,0%	65,55	5,49	94,9	2,3	23,5	0	335
Август	20,6	62,1%	59,46	4,90	94,9	2,1	23,2	0	329
Сентябрь	16,5	66,4%	61,66	3,65	95,1	2,1	18,2	45	195
Октябрь	11,0	73,2%	61,28	2,47	95,2	2,0	11,6	217	31
Ноябрь	4,4	78,7%	57,51	1,39	95,1	2,2	4,2	408	0
Декабрь	0,1	81,1%	72,35	0,87	95,1	2,1	-1,2	555	0
Ежегодный	**10,2**	**70,3%**	**751,98**	**3,26**	**94,9**	**2,3**	**10,8**	**3 040**	**1 296**
Источник	Грунтовой	Грунтовой	NASA	Грунтовой	Грунтовой	Грунтовой	NASA	Грунтовой	Грунтовой
Измерено в					м	10	0		

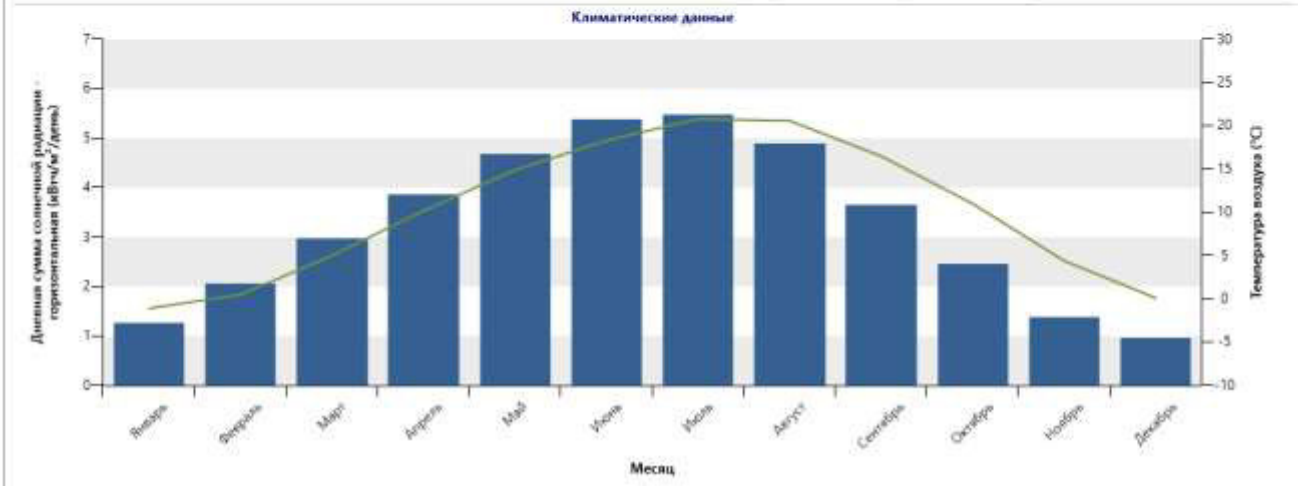

Fig.3. Climatic conditions of the hybrid power station

2. Wind turbine

Wind turbine is that system which extracts energy from wind by rotation of the blades of the wind turbine. The wind turbine is of the vertical type. The power generated from wind is not continuous its fluctuating. A wind turbine data and electricity generation from the wind turbine using RETScreen Expert software tool [6] are calculated. They are presented in Figure 4 and Figure 5, respectively.

3. Charge controller

Charge controller has basic function is that it control the source which is to be active or inactive. It simultaneously charge battery and also gives power to the load. The controller has over-charge protection, short-circuit protection, pole confusion protection and automatic dumpload function. It has also the function, which it should vary the power as per the load demand. It add the both the power so that the load demand can fulfill. When power is not generating the controller should extract power from battery and give it to the load.

4. Battery Energy Storage System (BESS)

DC power Batteries are charged and discharged in different mode. Bidirectional power electronic devices are regulating power flow between batteries and energy systems [4]. Based on the type of battery, it has various merits and demerits like cost, weight, size, power and energy capability. Lithium-Ion, Lead-Acid, Nickel Cadmium, Nickel Metal Hydride are important types of energy storage technologies.

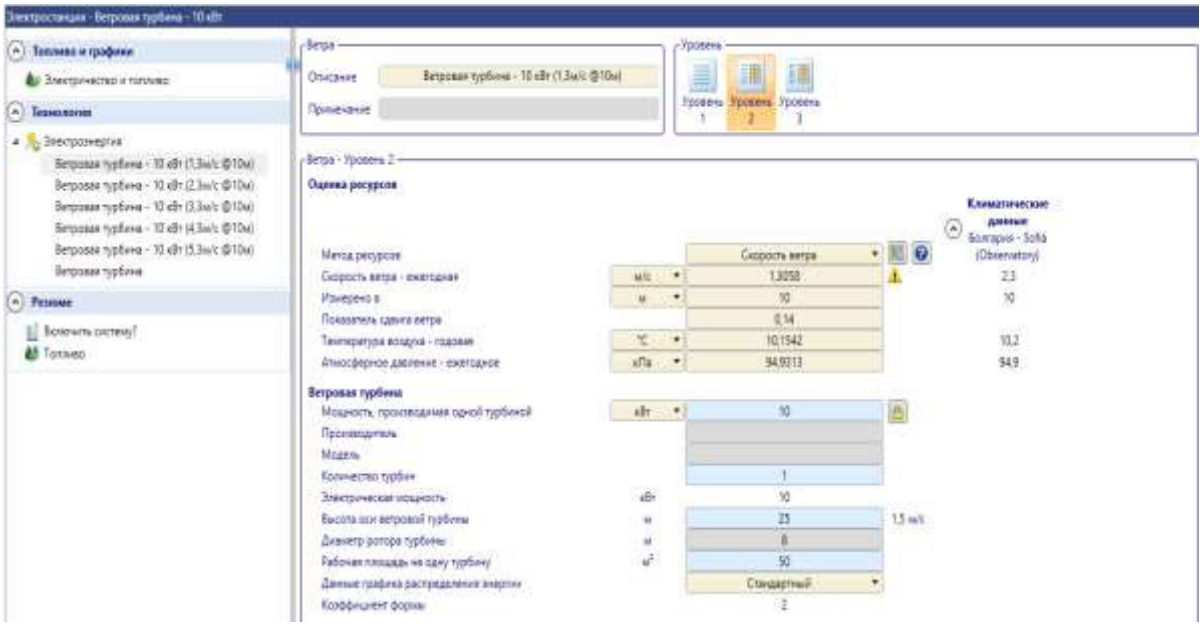

Fig.4. Wind turbine data

Скорость ветра м/с	Данные кривой мощности кВт	Данные графика распределения энергии МВт·ч
0	0	
1	0	
2	0	
3	0	1,9
4	0,19	5,7
5	0,67	11,6
6	1,25	18,7
7	2,09	26,3
8	3,22	33,5
9	4,57	40,1
10	5,89	45,8
11	7,8	50,7
12	8,87	54,6
13	9,44	57,7
14	9,63	59,9
15	9,83	61,3
16	9,91	
17	9,96	
18	10	
19	10	
20	10	
21	10	
22	10	
23	10	
24	10	
25	10	
26	10	
27	10	
28	10	

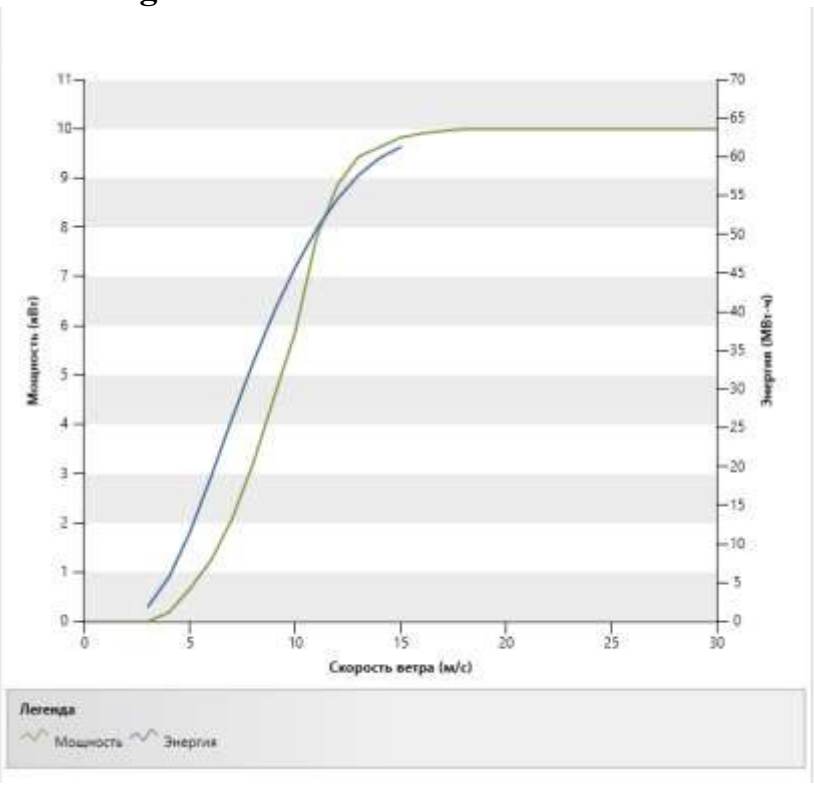

Fig.5.. Electricity generation from the wind turbine

The highest energy density among all types of batteries is Lithium-Ion batteries. They are currently used in cellular phones, computers, etc. and development of this technology is used in distributed energy storage applications. During coupled operation, changes in the outputs of wind and solar PV generation [5, 6] will change in the output of BESS and BESS must neutralize by quick changes in output power. Rate variation control or ramp rate control is applied for an associated coupled system to smooth their real power fluctuations [1]. The information is processed by the Battery Energy System controller and es-timates the State of Charge (SOC) of each battery cell and capacity of each battery cell and protects all the cells operate in the designed SOC range [5].

5. Inverter

Inverter is need to convert DC power into AC power. As our load working on the AC supply so we need to convert DC power. The input voltage, output voltage and frequency, and overallpower handling depends on the design of the specific device or the circuitry. The pure sign wave inverter is recommended, because it has minimal distortion and loses.

3. A MODEL OF THE HYBRID POWER STATION

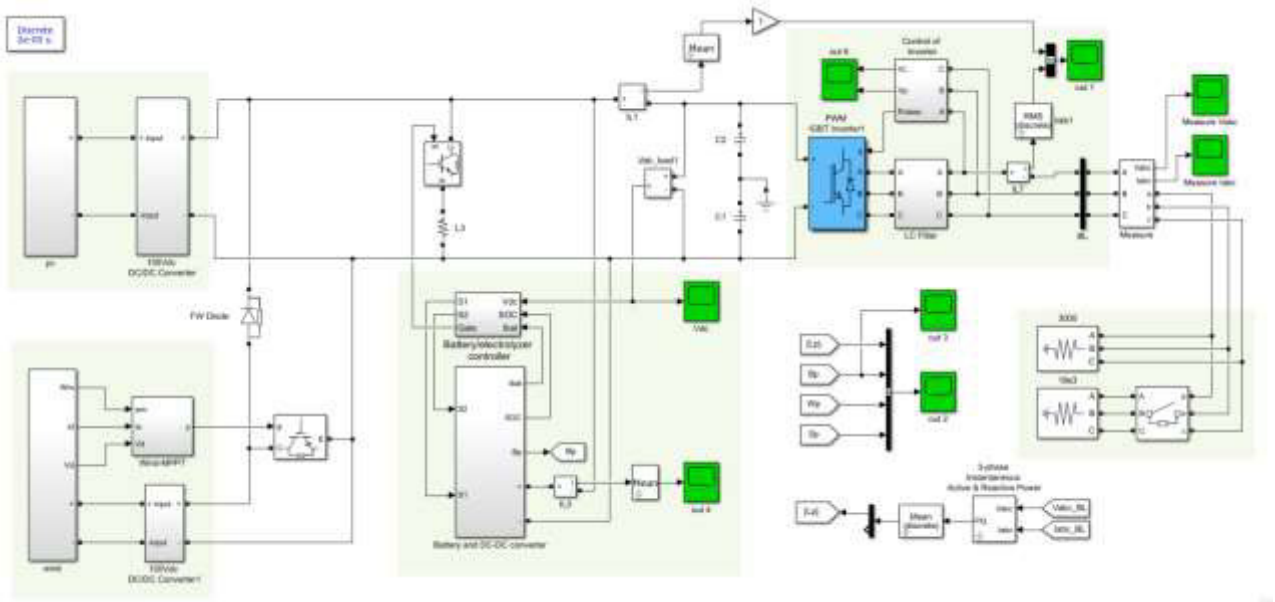

Fig.6. Block diagram of the simulated Hybrid Power Station

The entire system design of the hybrid energy system is simulated using SIMULINK. A 10-kW PV / wind / BESS (Battery Energy Storage System) hybrid system was considered.

Figure 6 show the simulation schematic for hybrid station with solar and wind sources.

All the energy sources are modeled using MATLAB [7] software tool to analyze their behavior. An easy control technique tracks the maximum power from the solar / wind energy source to accomplish much higher generating capacity factors. The simulation results prove the feasibility and reliability of this proposed system.

4. SIMULATION RESULTS

The simulation study of system parameters are presented below and to predict their actual characteristics three energy sources are modeled accurately in SIMULINK.

Several variants of the operation of the hybrid power plant are considered.

Simulation of different conditions of the hybrid system is performed. All these conditions are clearly observed in the list below.

Common conditions

The load demand to fulfill is 10 KW throughout the time scale except at 4 to 5 sec when it increases to 14 KW. Battery initial state-of-charge 60%.

Several simulation of the operation of the hybrid power plant are carried out.

Simulation 1 Case of variable weather conditions

- Solar energy drops its irradiance from 100% to 25 % from 2 sec.
- Wind turbine initially rotating at 5m/s excels to base speed 12m/s after 0.5 sec. Its rotating speed is decreased to 25 % of its base speed.

The simulation results of voltages and currents in the three phases, and voltage and current in batery in this case are shown in Figure 7 and Figure 8, respectively.

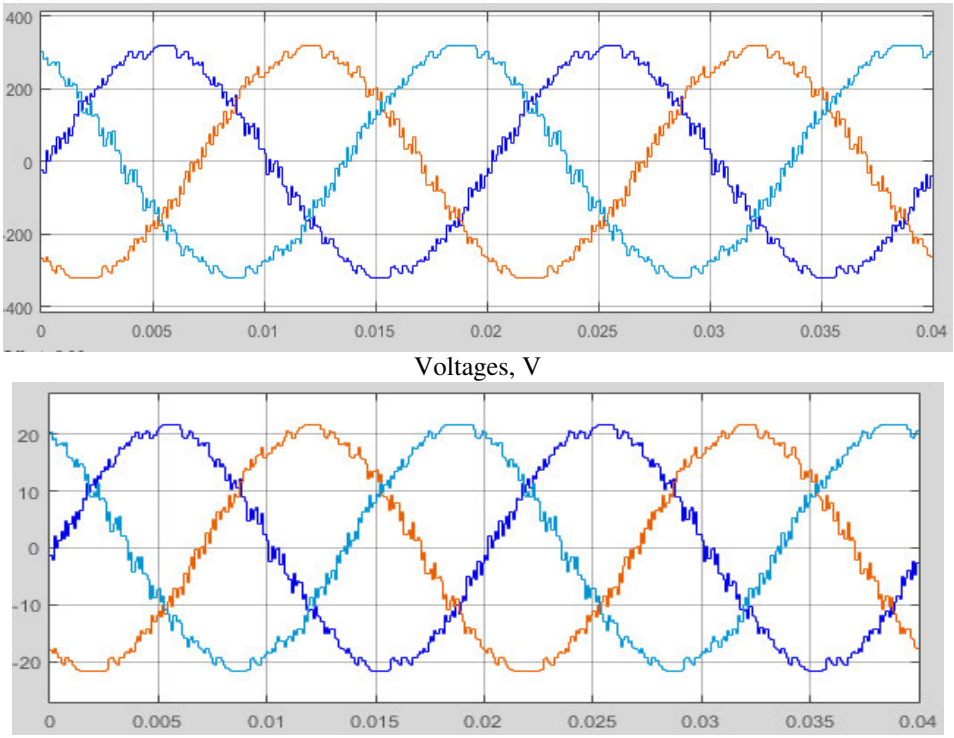

Fig.7. Voltages and currents in the three phases

The simulation results of generating Wind power and PV power in this case are shown in Figure 9.

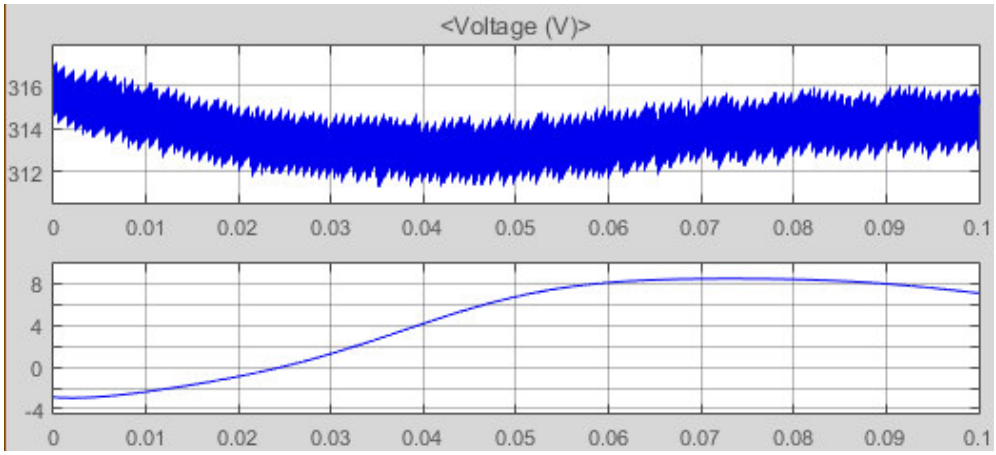

Fig.8. Voltages and current in the battery

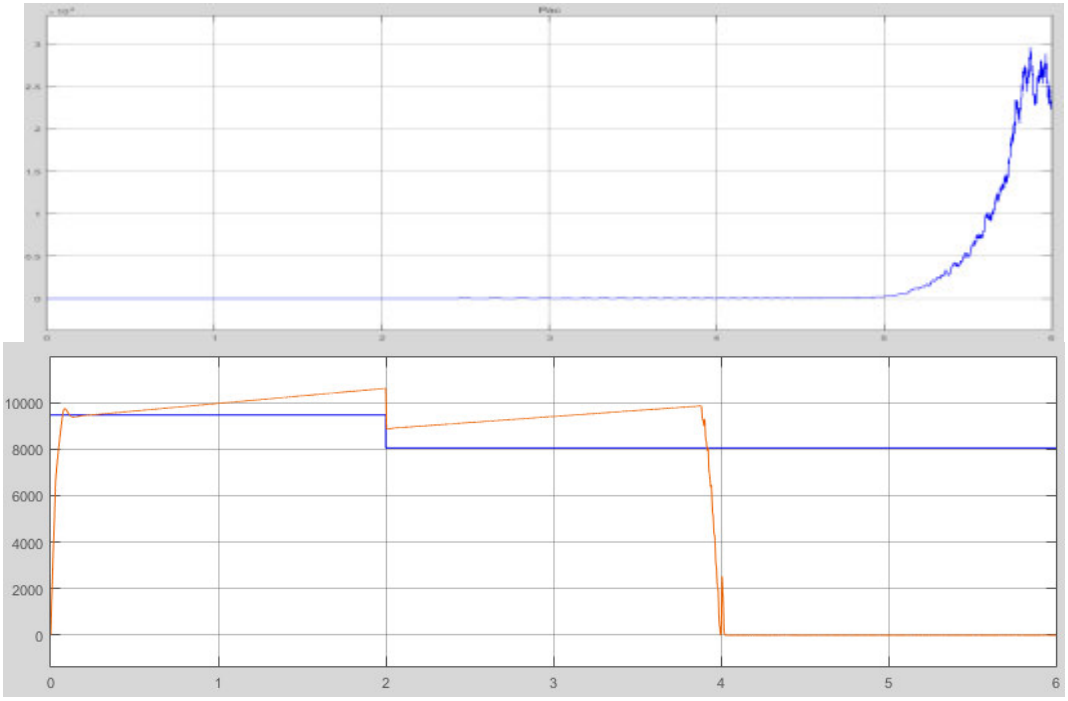

Fig.9. Generated Wind power and PV power in Wats

The harmonic analysis is shown in Figure 10. The integrated voltages and curents are close to sinusoid and THD has very small value.

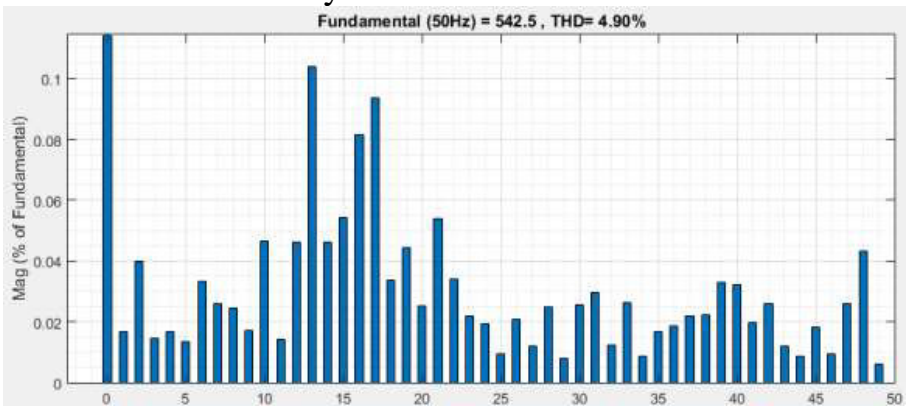

Fig.10. Harmonics analysis with two sources

Simulation 2 (maximum solar energy, while no wind power)

- Solar energy irradiance at 100%.
- Wind turbine rotating at 0 m/s.

In this case voltages and currents are close to ideal. The invertor vorks with maximum efficiency and low harmonics level. The level of battery voltage is stability, it can be shown in Figure 11.

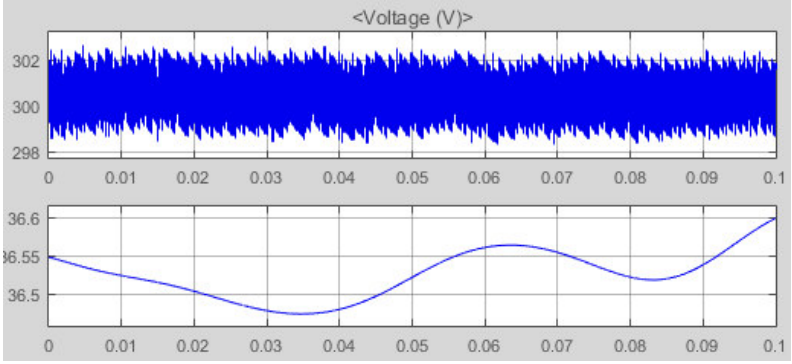

Fig.11. Batery volate in case of maximal PV power

Simulation 3 (maximum wind power, while no solar energy)

- Solar energy irradiance at 0%.
- Wind turbine rotating at 12 m/s.

In this case voltages and currents are close to ideal also. Generating Wind power increase significantly by relatively high speed of turbine. In can be shown in Figure 12.

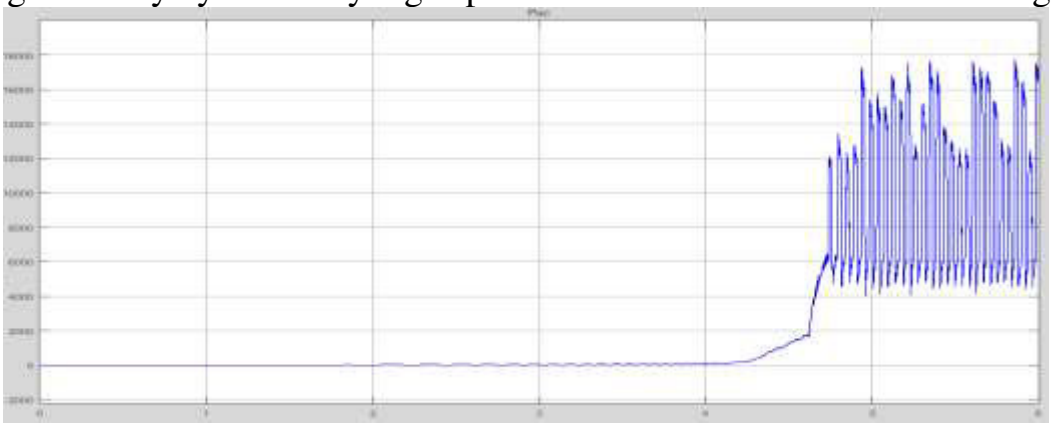

Fig.12. Generated maximal Wind power

Simulation 4 (Power station works with 60% of the installed power – 20/40)

- Solar energy irradiance at 20%.
- Wind turbine rotating at 5 m/s.

The simulation results of generating Wind power and PV power in this case are shown in Figure 13.

Simulation 5 (Power station works with 60% of the installed power – 40/20)

- Solar energy irradiance at 40%.
- Wind turbine rotating at 2.5 m/s.

The simulation results of generating Wind power and PV power in this case are shown in Figure 14.

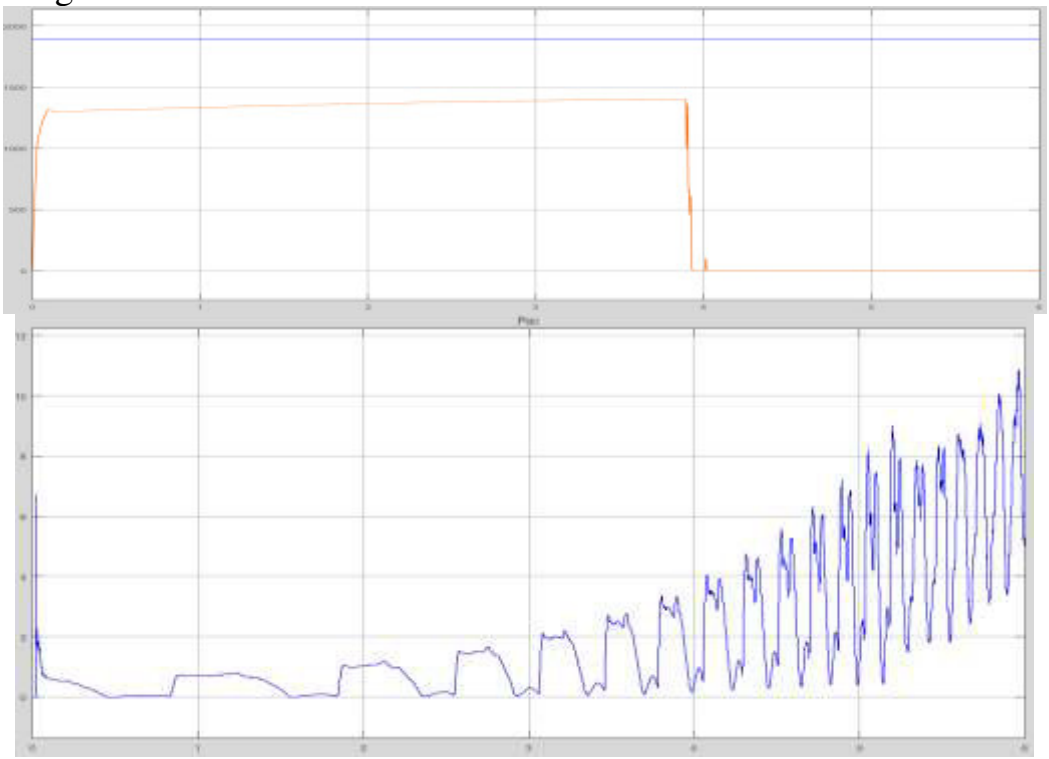

Fig.13. Generated Wind power and PV power (60% of the installed power – 20/40)

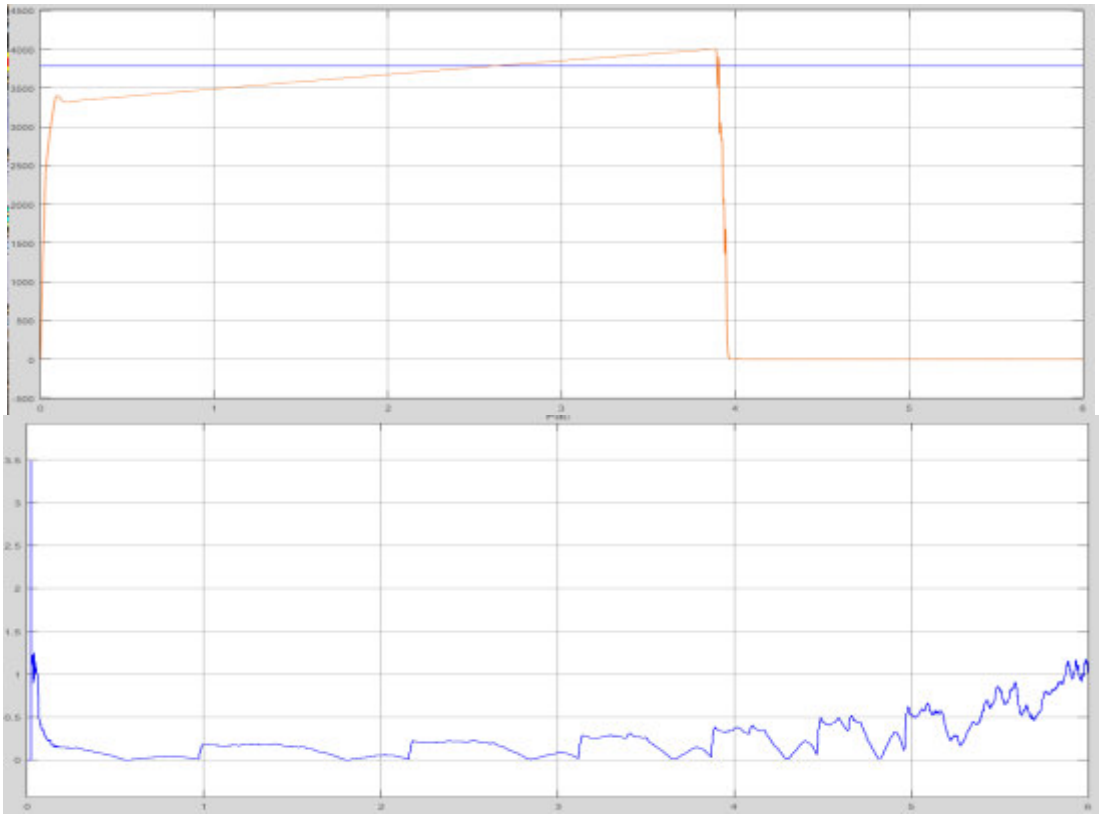

Fig.14. Generated Wind power and PV power (60% of the installed power – 40/20)

5. DISCUSSION

The electric power can be utilize where it generated so that it will reduce the transmission losses and cost.

There are several ways by which electricity can be generated using renewable sources such as solar, wind, biogas, etc. Individual generation of solar and wind energy is costlier.

The using the non conventional energy resources is highly safe for the environment as it doesn't produce any emission and harmful waste product like conventional energy resources. It is cost effective solution for generation. It only need initial investment. Cost reduction can be done by increasing the production of the equipment and stimulate our economy by creating jobs in the manufacturing and installation of solar and wind energy systems.

By using solar and wind integrated system we can electrify remote area, also in future it is applicable in smart grid to for metro cities avoid unwanted load shedding.

Solar and wind energy integrated technologies have great potential.

6. CONCLUSION

The power hybrid station with renewable generating sources - Photovoltaic plant and Wind-generator is considered. They are highly safe for the environment as it does not produce any emission and harmful waste product like conventional energy resources.

A model of hybrid power station in MATLAB is created. Simulations of the power station operation have been carried out in different modes.

The performance of hybrid power station is analysed.

The harmonic composition of the generated AC voltage with an industrial frequency is investigated.
The hybrid power station is good and effective solution for power generation than conventional energy resources.

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