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Solar-Wind Hybrid Systems For Power Generation

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Abstract – *Now a day's electricity is one of the foremost things for our day to day life activities in this technology driven world. As we all are oblivious of the fact that, new able sources of energy are depleting at extremely fast rate. So it's time for us to change like shifting the focus from conventional to non-conventional sources of energy to produce electricity. As the race for global industrialization begin late in 18th century, the developing technology made humans to depend on energy, so as the energy crisis begins, in this modern era, electricity become a most essential need of human beings, from household to industrial work .The output of the electricity produced by non-conventional sources is very less than their counterparts. Renewable sources do not have any detrimental effect on the environment. Solar-wind hybrid system is basically an integration of solar and a wind energy plant. It is also a small source to produce power in renewable form. It will help in providing the uninterrupted power supply. During bad weather conditions, the production can be shifted from one plant to other with the help of a micro controller. A microcontroller ensures the optimum utilization of resources and it also increases the efficiency of the combined system as compared to the individual mode of generation. It helps in decreasing the dependence on one single source and makes the system more reliable. The hybrid system can be used for everything like industrial and domestic applications.*

***Keywords**: Solar Energy, Wind Energy, PV Cell, Renewable Energy, Hybrid Power System, Electricity.*

I. INTRODUCTION

We require electricity for operating almost all the appliances we use in our day to day life. So it has become an indispensable part of our life. Now there are two ways to produce electricity first by using non-renewable sources of energy and second by renewable sources of energy.

With increase in population and advancement of technology, consumption of electricity is also increasing exponentially. Simultaneously, we have to increase the production of electricity also in order to meet the demands of growing population. The biggest disadvantage with the usage of conventional resources is that their usage causes pollution due to the production of various pollutants like a shin case of a coal power plant, smoke in case of diesel power plant, radioactive material in case of nuclear power plant. Maintaining these pollutants is not an easy task and it also requires a lot of money. So we have to find some other methods to produce electricity. The best possible way is by using non-conventional sources of energy. Out of all the possible options available in non-conventional sources of energy, solar and wind are the best methods. As tidal energy can be used only on the sea shores, ocean thermal energy can used in the middle of the sea and its set up is also very difficult. While solar and wind are available in all the areas of the world and setting up their power plant is also not a cumbersome task. The availability of solar energy is a major concern, as it is available for around 8 hours in a day on the other hand wind is available almost for 24 hours. But we can do one thing to make up for that problem by integrating these two together. During foul weather conditions one of them can be used while during normal weather both can be operated together. So in this paper we will be describing a solar-wind hybrid power system.

A. Solar Energy:

Solar energy is radiant light and heat from the Sun that is harnessed using a range of ever-evolving technologies such as solar heating, photovoltaic, solar energy system, solar architecture, molten salt power plants and artificial photosynthesis. It is an important source of renewable energy and its technologies are broadly characterized as either passive solar or active solar depending on how they capture and distribute solar energy or convert it into solar power. Active solar techniques include the use of photovoltaic systems, concentrated solar power and solar water heating to harness the energy. Passive solar techniques include orienting a building to the Sun, selecting materials with favourable thermal mass or light-dispersing properties, and designing spaces that naturally circulate air.

B. Wind Energy:

When air flows then it is having some kinetic energy with it which is known as wind energy. This kinetic energy is converted into mechanical energy by the wind turbine, which is used to rotate the shaft of the generator and then electricity is produced. The initial investment of the system varies depending on the type of turbine used. The best part about producing electricity with the help of wind energy is that wind is available for almost 24 hours in day, so there will not be any discontinuous production of electricity. The output varies with the speed of the wind.

C. Hybrid Systems:

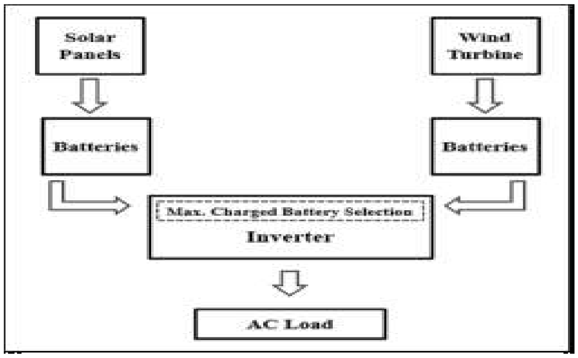


Fig-1: Block Diagram a hybrid system

Now we have become even more interested in usage of renewable energy sources as an alternative method of producing electricity. Hybrid systems are basically an integration of solar panels and wind turbine, the output of this combination is used to charge batteries, this stored energy can then be transmitted to local power stations. In this system wind turbine can be used to produce electricity when wind is available and solar energy panels are used when solar radiations are available. Power can be generated by both the sections at the same time also. The usage of batteries is to provide uninterrupted power supply. This system requires high initial investment. But there liability, long-life span and less maintenance make up for that disadvantage. The power output of the wind turbine is AC which is converted to DC with the help of a rectifier. The voltage can be stepped up or stepped down with the help of a 'SEPIC' converter which uses MOSFET switching. The micro controller is used in the system to control the switching between the converters with the help of a driver circuit. A CUK converter is used to control the power supply of solar panels.

II. COMPONENTS USED:

A. *Solar Panels*:

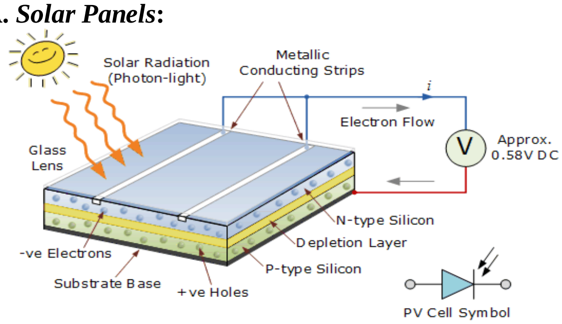


FIG-2: SOLAR CELL

A solar cell is used to convert solar energy into electric energy, it is also known as photovoltaic cell. It is ap-n junction diode which consists of two different layers of a semi- conductor material called as n and p region, n region is heavily doped and is thin while p region is lightly doped and is thick. The radiation falling on the surface of p-n junction diode can pass through the n side. Most of the

B. Wind Turbine:

Wind is a renewable source of energy. A wind turbine is used to convert the kinetic energy of the wind in to electric. The generator connected to the shaft of the blades converts the mechanical energy to electric energy. The wind turbine is of two types depending upon the rotating axis of the blades, first is vertical axis wind turbine and horizontal axis wind turbine. The output of the turbine depends on
the speed of the wind. The power generated by the turbine is fluctuating. In order to obtain continuous supply of power first the electricity is stored in a battery unit and then it is transferred to the load**.**

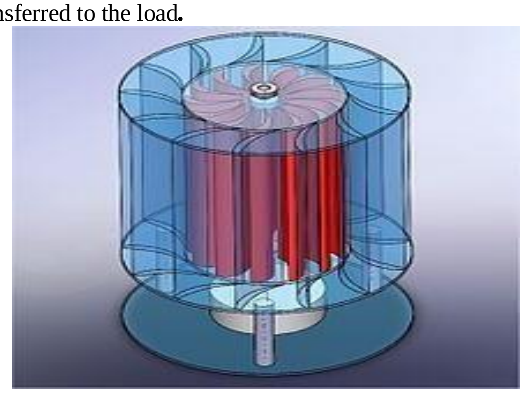


Fig 3:- Vertical Axis Wind Turbine

C. Batteries:

The batteries are used in order to store the electricity that is produced from wind and solar energy. The capacity of battery may vary depending on the size of wind turbine or solar power plant. Battery should be having low maintenance and charge leakage should also be low. Considering all these parameters free discharge type is the best option available. Multiple batteries can be connected in series and parallel to increase or decrease the capacity of the battery, depending upon the output from the hybrid systems. Primary (single-use or "disposable") batteries are used once and discarded; depletion region is contained in the p region which is lightly doped. The extent to which the n region can be penetrated is decided by the wavelength of the falling radiation. Electron–hole pairs are generated in the n and p region, due to the difference in potential the electrons move to the n region and holes towards the p region. The current starts flowing when an external load is connected to the terminals of the n and p regions. To make a solar panel multiple solar cells are connected in series and parallel combinations, they are connected in such a way that the output obtained is additive in nature. the electrode materials are irreversibly changed during discharge. Common examples are the alkaline battery used for flashlights and a multitude of portable electronic devices. Secondary (rechargeable) batteries can be discharged and recharged multiple times using an applied electric current; the original composition of the electrodes can be restored by reverse current. Examples include the lead-acid batteries used in vehicles and lithium-ion batteries used for portable electronics such as laptops and smart phones.

D. Inverter:

As we know that most of the electrical appliances require AC voltage, so first the DC output of the batteries will be converted into AC voltage with the help of an inverter and then it will be transferred to the loads. The inverter must be having over voltage protection, reverse polarity and short circuit protection. A power inverter, or inverter, is an electronic device or circuitry that changes direct current (DC) to alternating current (AC). The input voltage, output voltage and frequency, and overall power handling depend on the design of the specific device or circuitry. The inverter does not produce any power; the power is provided by the DC source. A power inverter can be entirely electronic or may be a combination of mechanical effects (such as a rotary apparatus) and electronic circuitry. Static inverters do not use moving parts in the conversion process. Circuitry that performs the opposite function, converting AC to DC, is called a rectifier.

E. Microcontroller:

The function of microcontroller is to compare the input of the both the power systems and then it operates there lay used, in order to charge the batteries. The DC voltage used in the batteries is converted to AC with the help of an inverter. To the secondary winding of the center tapped transformer used a MOSFET is connected. To make the current flowing in the primary winding alternative in nature a MOSFET is triggered at alternate intervals and in this manner way we get the AC current in the primary winding of the center tapped transformer. Microcontrollers are used in automatically controlled products and devices, such as automobile engine control systems, implantable medical devices, remote controls, office machines, appliances, power tools, toys and other embedded systems. By reducing the size and cost compared to a design that uses a separate microprocessor, memory, and input/output devices, microcontrollers make it economical to digitally control even more devices and processes. Mixed signal microcontrollers are common, integrating analog components needed to control non-digital electronic systems. In the context of the internet of things, microcontrollers are an economical and popular means of data collection, sensing and actuating the physical world as edge devices.

III. RENEWABLE ENERGY USAGE AND TARGET

Today, India's 275 GW of installed electricity generating capacity is significantly higher than 140 GW of peak demand. In fact, India's coal generation capacity alone is higher than its peak demand. Despite installed capacity exceeding power demand, some parts of the country face acute power shortages. The critical reasons are – coal supply shortages, high level of transmission and distribution losses, and poor financial health of utilities. Distribution companies that buy electricity generated with imported coal face significant and unpredictable upward pressure on tariffs. The objective of this Report thus is to explore financing requirements and possible business models for deployment of 40 GW of rooftop solar by 2022, and also assess the requirements and utilization of public finance for deploying and integrating 175 GW RE by 2022 – a major theme towards achieving the stated RE targets. While the report focuses on financing requirements for generation tariff parity in details, it also touches upon the finance requirements for grid expansion, grid integration and human resource aspects. The following technologies are covered in the chapters, across the generation, transmission and distribution segments of the renewable energy sector to meet the targets indicated below by 2022:

1. Solar (utility-scale, distributed, off-grid/mini-grid – 100 GW)
2. Wind (utility-scale – 60 GW)
3. Small hydro (5 GW)
4. Bio-energy (10 GW)

While the report captures all common elements across these technologies, it goes into an in-depth analysis for utility-scale solar and wind, and offers indicative analysis of decentralized and distributed solar. Presently, renewable energy accounts for ~12% of India's total installed power generation capacity, and approximately 5% of the total generation. The Government of India aims to reach a renewable energy capacity of 175 GW by 2022. 100 GW of this is planned through solar energy, 60 GW through wind energy, 10 GW through small hydro power, and 5 GW through biomass-based power projects. Of the 100 GW target for solar, 40 GW is expected to be achieved through deployment of decentralized rooftop projects, 40 GW through utility-scale solar plants, and 20 GW through ultra-mega solar parks. Considering these targets, renewable (solar, wind and hydro) will account for ~10% of the total energy mix, by 2022 (IESS 2047)

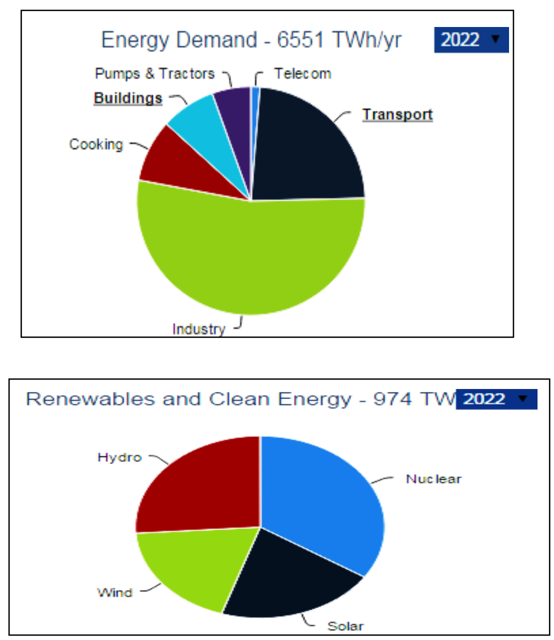


Fig 4: Possible share of RE in India's Energy Mix in 2022

IV. RENEWABLE ENERGY: GLOBAL OVERVIEW

In 2016, an estimated 161 GW (including large hydro) of renewable energy capacity was added worldwide. This is the largest annual increase till date, up almost 9% compared to 2015, taking the cumulative installed renewable capacity to nearly 2,017 GW (including large hydro) at the end of 2016. Solar PV dominated the landscape with 47% of newly installed renewable power capacity, while wind and hydropower accounted for about 34% and 15.5% respectively. Thus, renewable accounted for an estimated 62% of net additions to global power generating capacity in 2016. In India, wind power and solar PV capacity increased substantially, and bio-power generation was up 8% as compared to 2015. Top 6 RE countries are summarized in Fig. If large hydro is accounted for, top countries for total installed renewable electric capacity continued to be China, the United States, Brazil, Germany and Canada. Excluding hydro, the top countries were China, the United States and Germany, followed by Japan, India and Italy, and Spain and the United Kingdom. In 2016, global new investments in renewable (excluding large hydro) fell by 23% to $241.6 billion, the lowest since 2013, but roughly double that of fossil fuel generation for the fifth consecutive year. Wind followed closely at $112.5 billion globally, down 9% from 2015, bio fuels $2.2 billion (down 37%), biomass and waste $6.8 billion (remained steady) and small hydro $3.5 billion. A combination of two factors, viz. lower costs of technologies (a positive trend), and considerable slowdown of renewable energy financing in some emerging markets like China and Japan (a negative trend), were the key reasons for fall in investments in 2016. The bright spot in investments was seen in assets financing, which total $110.3 billion, up 17% from 2015. Purchase of assets such as wind farms and solar parks reached a highest-ever figure of $72.7 billion, while corporate takeovers reached $27.6 billion, 58% up from 2015. Table ranks countries as per capacity addition in 2016 and cumulative installed capacity till end 2016 respectively. China is undoubtedly seen as the leader in the RE sector, topping both in cumulative and annual capacity addition (solar, wind, and hydro), while India ranks 4th in terms of cumulative installed capacity of wind, and annual capacity addition of solar PV and wind in 2016.

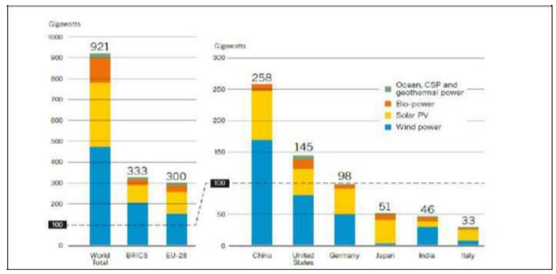


Fig: 5 Renewable 2017, Global Status Report

Table 1.1: Country Ranking by Capacity Addition in 2016

	1		2		3		4		5		World
		GW		GW		GW		GW		GW	GW
Geothermal	Indonesia	0.2	Turkey	0.2	Kenya	0.03	Mexico	.015	Japan	.001	0.447
Hydropower	China	8.9	Brazil	5.3	Ecuador	2.0	Ethiopia	1.5	Vietnam	1.1	25
Solar PV	China	34.5	US	14.8	Japan	8.6	India	4.1	UK	2	75
Wind	China	23.4	US	8.2	Germany	5	India	3.6	Brazil	2	55
Bio-Diesel	US	-	Brazil	-	Argentina	-	Germany	-	Indonesia	-	-

Renewable 2017, Global Status Report

Table 1.2: State & U.T. Wise Targets and Installed Capacity (As of 31 March 2017)

		RE Target 2022	Installed Capacity by March 2017 (MW)		
			State Sector	Private Sector	Total
1	Delhi	2,762	-	56.27	56.3
2	Haryana	4,376	59.30	192.00	251.3
3	Himachal Pradesh	2,276	256.61	575.93	832.5
4	Jammu & Kashmir	1,305	108.03	51.36	159.4
5	Punjab	5,066	127.80	1,025.30	1,153.1
6	Rajasthan	14,362	23.85	6,213.95	6,237.8
7	Uttar Pradesh	14,221	25.10	2,274.73	2,299.8
8	Uttarakhand	1,797	62.87	452.94	515.8
9	Chandigarh	153	-	17.32	17.3
Northern Region Total		**46,318**	**663.56**	**10,859.80**	**11,523.4**
10	Goa	358	0.05	0.71	0.8
11	Gujarat	17,133	8.00	6,663.89	6,671.9
12	Chhattisgarh	1,808	11.05	421.81	432.9
13	Madhya Pradesh	12,018	83.96	3,453.93	3,537.9
14	Maharashtra	22,045	208.13	7,439.47	7,647.6
15	D&N Haveli	449	-	2.97	3.0
16	Daman & Diu	199	-	10.46	10.5
Western Region Total		**54,010**	**311.19**	**17,993.24**	**18,304.4**
17	Andhra Pradesh	18,477	89.50	6,074.92	6,164.4
18	Telangana	2,000	-	1,545.88	1,545.9
19	Karnataka	14,817	155.33	7,302.64	7,458.0
20	Kerala	1,970	145.02	193.70	338.7
21	Tamil Nadu	21,508	122.70	10,502.30	10,625.0
22	Puducherry	246	-	0.08	0.1
Southern Region Total		**59,018**	**512.55**	**25,619.52**	**26,132.1**
23	Bihar	2,762	70.70	221.52	292.2
24	Jharkhand	2,005	4.05	23.27	27.3
25	Odisha	2,377	6.30	188.15	194.5
26	West Bengal	5,386	91.95	332.69	424.6
27	Sikkim	86	52.11	-	52.1
Eastern Region Total		**12,616**	**225.11**	**765.63**	**991.7**
28	Assam	688	30.01	15.88	45.9
29	Manipur	105	5.45	0.03	5.5
30	Meghalaya	211	31.03	0.01	31.0
31	Nagaland	76	30.67	0.50	31.2
32	Tripura	105	16.01	5.09	21.1
33	Arunachal	539	104.61	0.27	104.9
34	Mizoram	97	41.47	0.10	41.6
North Eastern Region Total		**1,821**	**259.25**	**21.88**	**281.1**
35	Andaman & Nicobar	27	5.25	6.56	11.8
36	Lakshadweep	4	-	0.7	0.7
Islands Total		**31.0**	**5.25**	**6.73**	**12.5**
37	Others	720			
All India Total		**174,534.0**	**1,976.91**	**55,267.33**	**57,244.24**

V. INDIA'S RENEWABLE ENERGY ACHIEVEMENTS IN LAST 4 YEARS:

India Government has revealed the main achievements in the renewable energy sector in the last 4 years. The government said $42 billion investment was made in renewable energy in India during last 4 years. India's renewable power installed capacity has reached over 70 GW. Over 40 GW renewable power capacities are under different stages of construction / tenders. India stands 4th in wind power, 5th in renewable power and 6th in solar power installed capacity globally. Solar energy capacity is increased by over 8 times from 2.63 GW in 2014 to 22 GW. India's wind energy capacity is increased by 1.6 times from 21 GW in 2014 to 34 GW. India announced bidding for 115GW renewable power projects up to March 2020. India is well on track to achieving 175 GW target of installed renewable energy capacity. Different projects: KUSUM (Kisan Urja Suraksha evam Utthaan Mahabhiyan) Scheme: 27.5 lakh solar pumps (17.50 lakh standalone + 10 Lakh Grid-connected) 10 GW of Solar Power Plants of intermediate capacity of 0.5–2 MW 50,000 Grid-connected tube-wells/lift irrigation and drinking water projects SRISTI (Sustainable Rooftop Implementation for Solar Transfiguration of India) India notified competitive bidding guidelines for procurement of solar and wind power in 2017. India discovered the lowest tariff of Rs. 2.44 per unit for solar and Rs. 2.43 per unit for wind. India will inaugurate the first solar plant bid at Rs. 2.44 in August 2018. India has waived the Inter State Transmission System charges and losses for inter-state sale of solar and wind power for projects to be commissioned by March 2022. This will encourage setting up of the projects in states that have greater resource potential and availability of suitable land**.** The ministry has also brought out one tender for setting up 2000 MW solar-wind hybrid in existing projects. India has enhanced target for Solar Parks from 20 GW to 40 GW. India has sanctioned 41 Solar Parks in 21 states with aggregate capacity of over 26 GW. Largest Solar Park of 2 GW capacities in Pavagada, Karnataka is under implementation. India announced new Solar Park policy to encourage participation by private parties and CPSUs in setting up Solar Parks. Off-shore from Tamil Nadu and Gujarat coast provides among the best locations from wind power generation**.**

VI. HYBRID ENERGY SYSTEMS

A. *Block Diagram*:

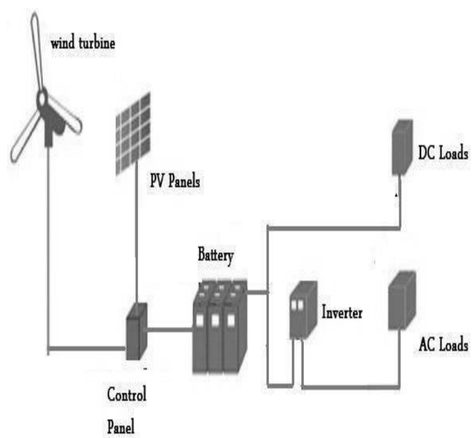


Fig -6: **Hybrid Systems**

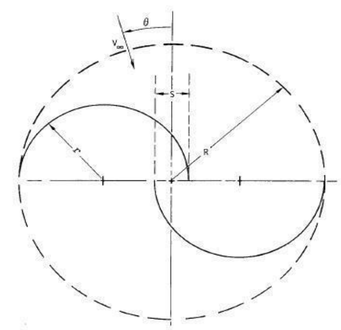
Now the required amount of electricity can be produced depending on the environmental conditions, by using two systems at the same time or by using only one, according to the conditions pertaining at that point of time.

VII. SAVONIUS TURBINE

Savonius turbine is a type of vertical axis wind turbine used for converting the force of wind into torque on a rotating shaft. The turbine consists of a number of aero foils usually but not always vertically mounted on a rotating shaft or framework either ground stationed or tethered in airborne systems. Most anemometers are Savonius turbines for this reason, as efficiency is irrelevant to the application of measuring wind speed. Much larger Savonius turbines have been used to generate electric power on deep-water buoys, which need small amounts of power and get very little maintenance. Design is simplified because, unlike with horizontal axis wind turbines (HAWTs), no pointing mechanism is required to allow for shifting wind direction and the turbine is self-starting. Savonius and other vertical-axis machines are good at pumping water and other high torque, low rpm applications and are not usually connected to electric power grids. In the early 1980s Risto Joutsiniemi developed a helical rotor (wiki: fi) version that does not require end plates, has a smoother torque profile and is self-starting in the same way a crossed pair of straight rotors is.

A. Operation of Savonius Turbine:

Aerodynamically it is a drag device consisting of 2 or 3 scoops. Looking down on the rotor from the above, a two scoop machine would like an S shape in cross section. Because of the curvature, the scoop experience less drags when moving against the wind than moving with the wind. The differential drag causes the turbine to spin. Because they are drag type devices, Savonius turbines extract much less of wind's power than other similarly sized lift type turbines. Much of the swept area of a Savonius rotor may be near the ground, if it has a small mount without an extended post , making the overall energy extraction less effective due to the lower wind speeds found at lower heights**.**



Schematic of the two-bucket Savonius rotor with 180° buckets.

VIII. THEORETICAL CALCULATIONS:

Overall power generated by system is the summation of the power generated by the solar PV panel and power generated by the wind turbine. Mathematically, it can be represented as,

$$P_T = N_W * P_w + N_s * P_S$$

Where,

Total power generated= P_T

Power generated by wind turbines= P_W

Power generated by solar panels= P_S

No. of wind turbine = N_W

No of solar panels used= N_W

A. *Calculations for wind energy:*

The power generated by wind energy is given by,

Power = (density of air * swept area * velocity cubed)/2

$$\mathbf{P_W = ½.(A_W)(V)^3}$$

Where,

P is power in watts (W)

ρ is the air density in kilograms per cubic meter (kg/m³)

A_W is the swept area by air in square meters (m²)

V is the wind speed in meters per second (m/s).

B. Calculations for solar energy:

To determine the size of PV modules, the required energy consumption must be estimated. Therefore, the power is calculated as

$$P_S = Ins.(t) * A_S * Eff.(p\,v)$$

Where,

Ins. (t) = isolation at time t (kw/ m^2)

A_S = area of single PV panel (m^2)

Eff. (p v) = overall efficiency of the PV panels and dc/dc converters.

Overall efficiency is given by

$$Eff.(p\,v) = H * PR$$

Where,

H = Annual average solar radiation on tilted panels.

PR = Performance ratio, coefficient for losses

C. Cost of the system:

The total cost of the solar-wind hybrid energy system is depend upon the total no of wind turbines used and total no of solar panels used. Therefore the total cost is given as follows

Total cost = (No. of Wind Turbine* Cost of single Wind Turbine) + (No. of Solar Panels * Cost of single Solar Panel) + (No. of Batteries used in Battery Bank * Cost of single Battery)

$$C_T = (N_W * C_{WT}) + (N_S * C_{SP}) + (N_B * C_B)$$

Where,

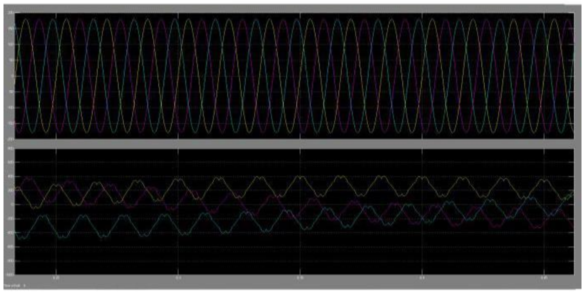
C_T is the total cost in Rs C_{WT} is the cost of single wind turbine C_{SP} is the cost of single solar panel in Rs C_B is the Cost of single Battery in Rs N_W is the number of wind turbine used N_S is the number of solar panels used N_B is the number of Batteries used in Battery Bank. Cost effectiveness of different solar agricultural pumping options:

Option A: Individual Solar Pumps: Upfront cost of INR 21 crores (at Rs. 150/Wp and replacement of 5 hp grid pump with 3 hp solar pump)

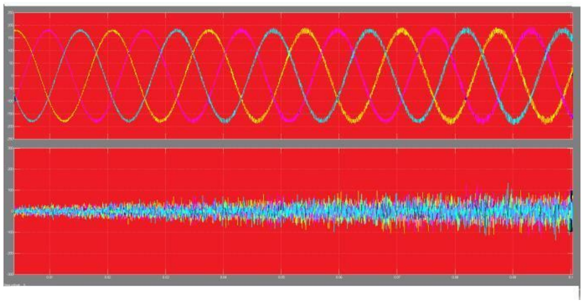
Option B: Solar powered feeder: 1.4 MW solar plant to offset yearly energy use. @ Rs. 5.5/kWh, yearly payment of Rs. 1.3 crores, or an NPV of INR 11.1 crores over 20 years.

Option C: Solar powered feeder with energy efficient pumps: 0.86 MW solar plant (40% reduction due to efficient pump). Existing pump replaced with a 5 star pump @ Rs. 35,000/pump. Yearly payment of Rs. 0.99 crores (incl. pump replacement cost spread over 20 years), or an NPV of Rs. 8.4 crores over 20 years. Assumptions: 11 kV feeder, with 500 pumps (avg 5 hP), usage of 1200 hours/year; discount rate: 10%

Solar output and wind output in rural areas using MATLAB.



Solar output



Wind output

ADVANTAGES:

The advantages covered by the propose systems are listed as:

- Overcoming disadvantages of standalone renewable electrical energy generation system.
- Since, the system doesn't have microcontroller or microprocessor the complexity of system testing and understanding became easy in terms of difficulties.
- System maintains is remarkably reduced and becomes easy.
- Renewable energy sources like, sun, wind, Are utilized so, no waste production.
- Producing clean friendly environment, renewable energy.
- Once the system is designed and developed or manufactured, the installation of system is easy.
- Within certain time period the installation cost gets covered.
- If the system gets damaged in case, no need of changing entire system or subsystem. Just, changing a damage component will work out**.**

DISADVANTAGES:

There's no system without having a disadvantage. So the systems have disadvantages as follow:

- The first time installation cost is huge in terms of finance.
- The circuit designing complexity is more as there in no micro-computer for controlling action.

FUTURE SCOPE:

As the awareness of non-renewable sources and pollution causes by them, the clean energy production with renewable sources is widely preferred and day by day implementation of such sources going on, so, research and resources are also increasing for such plants and projects. As the first time installation cost is higher due to design and manufacturing perspective. The system can be monitories using graphical user interference on computer. So, the whole information will be available to user and/or stored regarding further applications and development.

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