Emerging Trends in Integrating Eco-Friendly Energy Resources for Green Energy in Micro Grid

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Abstract:
Electrical energy is provided worldwide by cable or overhead transmission lines. However, power systems are still needed to locations which are isolated or far from electrical energy suppliers. Renewable energy based distributed generators (DGs) play a dominant role in electricity production. Distributed generation based on wind, solar energy, biomass, mini-hydro along with use of fuel cells and micro-turbines will give significant momentum in near future. Uncertainty and intermittent characteristics of wind speed, solar irradiation level, ambient temperature, and load are also considered in system control and operation. In this present situation the development of intelligent system that integrate Eco-friendly energy resources such as wind, photovoltaic system, and fuel cell for clean energy using MATLAB is designed & tested for its reliability and cost effectiveness under different environment condition. Also the initial cost, net present cost, operating & maintenance cost, payback period and emission details of the entire micro-grid system is calculated to check the commercial viability of the system.

Index Terms: Micro-Grid, Distributed Generation Unit, Eco-friendly energy resources, clean energy, Fuel cell, Super-capacitor bank

I. INTRODUCTION

Develop an intelligent system that can integrate renewable resources -- wind turbine system, photovoltaic system and fuel cell as a backup system to provide continuous electricity without failure thus improves the system reliability. This kind of system helps in meeting the energy requirement without any consequences of depleting the fossil fuels, or facing the potential hazards of Nuclear Setups and also reducing harmful emissions compared to conventional backup systems. Also calculate the overall costing of the project with payback period and emission details to check commercial viability of the system. The operation of our present industrial civilization is wholly dependent on access to a very large amount of energy of various types of fossil fuels that are exhaustible and at the same time pollutant of environment. So to save the human life from the permanent damage done by fossil fuels and to continue the industrial growth we have to stop the use of fossil fuels like coal, oil, gas, nuclear and try to develop alternative energy resources and try to develop sufficient energy so that the energy requirement of the human can be achieved. This paper constructs production models for the various energy sources we use and projects their likely supply evolution out to the year 2100. [1] The sun is the ultimate source of most other sources of energy. The heat of the sun can be trapped by using solar panels to heat water or converted to electricity by means of photovoltaic cells. Solar is an emerging technology for clean energy but alone it cannot cope up with current demand of world energy but can be integrated with some other energy is the ideal effort to meet the requirement. Extracting the detail from the source wind energy is free, no pollution, easy construction and efficient conversion of wind into electricity but it is not enough to come up the continuous energy demand and same cannot be used as a standalone energy source due to its dependence on weather condition. Fuel cell technology contains a variety of approaches toward remaking conventional batteries into biology-based batteries. The variety of applications in which these power cells could possibly work also suggests that fuel cell technology has a bright future. Microgrid is just nothing but practically controlling the generation of electricity and maintaining its use for adequate requirement so all the power system can operate reliably.

II. NON CONVENTIONAL ENERGY RESOURCES

A. Renewable energy potential of India
In recent years, India has emerged as one of the leading destinations for investors from developed countries. India is now the eleventh largest economy in the world, fourth in terms of purchasing power. As we can see from the above figure, Renewable resources are becoming the major player in generation of electricity in near future. So let’s check the renewable energy potential in India. Table I. shows the renewable energy potential of India.

B. Wind Energy
There are two major kinds of wind generators.
- Horizontal-axis
- Vertical-axis

<table>
<thead>
<tr>
<th>TABLE I. THE RENEWABLE POTENTIAL OF INDIA</th>
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1) **Vertical-axis wind turbines (VAWTs):**

Vertical-axis wind turbines (VAWTs) are pretty rare. The only one currently in commercial production is the Darrieus turbine, which looks kind of like an egg beater as shown in Figure 1 Vertical-Axis wind turbine. In a VAWT, the shaft is mounted on a vertical axis, perpendicular to the ground. VAWTs are always aligned with the wind, unlike their horizontal-axis counterparts, so there's no adjustment necessary when the wind direction changes; but a VAWT can't start moving all by itself – it needs a boost from its electrical system to get started. Instead of a tower, it typically uses guy wires for support, so the rotor elevation is lower. Lower elevation means slower wind due to ground interference, so VAWTs are generally less efficient than HAWTs. On the upside, all equipment is at ground level for easy installation and servicing; but that means a larger footprint for the turbine, which is a big negative in farming areas. VAWTs may be used for small-scale turbines and for pumping water in rural areas, but all commercially produced; utility-scale wind turbines are horizontal-axis wind turbines (HAWTs) as shown in Figure 2.

![Vertical-axis wind turbine](image)

**Figure 1. Vertical-axis wind turbine**

2) **Horizontal-axis wind turbines (HAWTs):**

As implied by the name, the HAWT shaft is mounted horizontally, parallel to the ground. HAWTs need to constantly align themselves with the wind using a yaw-adjustment mechanism. The yaw system typically consists of electric motors and gearboxes that move the entire rotor left or right in small increments. The turbine's electronic controller reads the position of a wind vane device (either mechanical or electronic) and adjusts the position of the rotor to capture the most wind energy available. HAWTs use a tower to lift the turbine components to an optimum elevation for wind speed (and so the blades can clear the ground) and take up very little ground space since almost all of the components are up to 260 feet (80 meters) in the air.

![Horizontal-axis wind turbine](image)

**Figure 2. Horizontal-axis wind turbine**

3) **Wind Energy in India:**

India is surpassed only by Germany as one of the world's fastest growing markets for wind energy. By the mid 1990s, the subcontinent was installing more wind generating capacity than North America, Denmark, Britain, and the Netherlands. The ten machines near Okha in the province of Gujarat were some of the first wind turbines installed in India. These 15-meter Vestas wind turbines overlook the Arabian Sea. In 2006, there is an installed capacity of 4,430 MW; however, ten times that potential or 46,092 MW, exists.

![Wind Energy in India](image)

**Figure 3: General representations of Solar Cell produce AC supply**

C. **Solar Energy**

1) **General representation of AC supply produced by Solar Cell:**

The solar cell works in three steps:

1. Photons in sunlight hit the solar panel and are absorbed by semiconducting materials, such as silicon.
2. Electrons (negatively charged) are knocked loose from their atoms, allowing them to flow through the material to produce electricity. Due to the special composition of solar cells, the electrons are only allowed to move in a single direction.
3. An array of solar cells converts solar energy into a usable amount of direct current (DC) electricity.

Figure 3 shows the General representation of AC supply produced by Solar Cell.

![Solar Energy](image)
Figure 4 shows a simplified representation of the Sun position in the sky [2]. The Sun height, denoted $h$, is the angle between the Sun direction and the horizontal plane. This angle is the most important specification of the Sun position. It is presented by this equation:

$$\sin h = \sin \theta \sin \delta + \cos \theta \cos \delta \cos \omega$$

(1)

Where,

$\theta$: Latitude of the location in degrees,

$\delta$: Declination angle of the sun in degrees

$\omega$: Hour angle

To determine the Total Solar Radiation, must determine the Direct and Diffuse Solar Radiation.

Direct Solar Radiation ($I_d$): The amount of solar radiation from the direction of the sun. The direct solar radiation ($I_d$) on a horizontal surface can be written as follows:

$$I_d = 1230. \exp(-1/3.8 \sin(h+1.6))$$

(2)

Diffuse Solar Radiation ($D_h$): Diffuse radiation is scattered out of the direct beam by molecules, aerosols, and clouds. The instantaneous diffuse solar radiation ($D_h$) can be approximated using this formula:

$$D_h = 125.(\sinh)^{0.4}$$

(3)

Figure 5: Mechanism of Fuel Cell with Using Hydrogen as its Fuel

If free electrons or other substances could travel through the electrolyte, they would disrupt the chemical reaction. Whether they combine at anode or cathode, together hydrogen and oxygen form water, which drains from the cell. As long as a fuel cell is supplied with hydrogen and oxygen, it will generate electricity.

III. ENERGY STORAGE BANK AND SUPER CAPACITOR BANK

An energy storage bank is an electrical battery which is a combination of one or more electrochemical cells, used to convert stored chemical energy into electrical energy. Batteries are quite difficult to model as they undergo thermally - dependant electrochemical processes while delivering and accepting energy. Thus the electrical behavior of a battery is a nonlinear function of a number of constantly changing parameters such as internal temperature, state-of- charge, rate of charge/discharge, etc. Super-capacitors are a sort of electric double-layer capacitors which are electrochemical capacitors that have an unusually high energy density when compared to common capacitors, typically on the order of thousands of times greater than a high capacity electrolytic capacitor. [3]
A. Combining Super Capacitor Bank & Battery

Batteries are one of most cost-effective energy storage technologies; however, the use of batteries as energy buffers is somehow problematic, since it is hard to recover from rapid power fluctuations without dramatically reducing the batteries’ lifetimes. On the other hand, energy storage in a super-capacitor is static charge rather than energy storage in a battery; thus the super-capacitor has a higher power density than a battery. When it comes to accomplishing better power and energy performances, combining these two energy storage devices is advantage.

- To gain better power & energy performances,
- Smaller battery size,
- Almost no limit on of their charge-discharge cycles,
- Requires no maintenance,
- Do not use toxic materials,
- The super-capacitors as a short-term energy storage device are utilized to compensate for fast changes in the power output power, while the battery as long-term energy storage devices is applied to meet the energy demand.

![Figure 6: Parallel Connection of Super-capacitor bank, battery bank and electrical load](image)

IV. MICROGRID

Micro-grids comprise LV distribution systems with distributed energy resources (micro turbines, fuel cells, PV, etc.) together with storage devices (flywheels, energy capacitors and batteries). Such systems can be operated in a non-autonomous way, if interconnected to the grid, or in an autonomous way, if disconnected from the main grid. The operation of micro-sources in the network can provide distinct benefits to the overall system performance, if managed and coordinated efficiently. Figure 7 shows the sample micro-grid.

![Figure 7. Sample Micro-grid](image)

V. SIMULATION SETTING FOR DESIGNED MICROGRID POWER SYSTEM

Simulation work is done in MATLAB R2011a. Here STANDALONE system is taken under consideration for simulation work.

A. Specifications and requirements of the entire microgrid power System

For the simulation purpose, Selected site: Veraval, Gujarat. Average load capacity in the micro grid is 200 kW, Maximum generator capacity of a used wind turbine generator: 100 kW Number of Wind Turbine engaged: 9 wind turbine generators Maximum generator capacity of used photovoltaic system: 220 kW Maximum generator capacity of fuel cell system which is backup one of the micro-grid power system: 200 kW Maximum battery capacity is 2000 kW and its initial value is 800 kW. Month under consideration is May.

B. System settings for the photovoltaic system part

For photovoltaic system part, The engaged photovoltaic panel is Aditya series WS 300 produced by Waaree. Its specifications are, Rated power is 300 watts, The voltage at max power is 35V, The weight is 29 kg.

Dimensions (Length*Width*Height) is 1960*990*42 mm. Annual average possibility of sunshine in Veraval, Gujarat is 60.7%.

The solar tracking system is assumed to work perfect.

C. System setting for the wind turbine system part

The annual variability of long-term mean wind speeds at site across India shows a normal distribution with a standard deviation of 6 percent. This result plays important role in the assessment of the uncertainty in the prediction of wind farm energy production. The simulation for wind turbine generation chooses a standard deviation of 6 percent which can represent wind speed in Veraval, Gujarat. Wind Turbine Power is expressed by the following equation

\[ P = 0.5 \rho A C_p V^3 N_s N_b \]  

Where, \( P \) = power in watts  
\( \rho \) = air density (about 1.225 kg/m\(^3\) at sea level, less higher up)  
\( A \) = rotor swept area, exposed to the wind (m\(^2\))  
\( C_p \) =coefficient of performance (0.59 [Betz limit] is the maximum theoretically Possible; 0.35 for a good design)  
\( V \) = wind speed in meters/sec  

There are three major messages delivered from this definition, namely as:

1. Microgrid is an integration platform for supply-side (micro-generators) and demand-side resources (storage units and (controllable) loads) located in a local distribution grid.
2. A Microgrid should be capable of handling both normal state (grid-connected) and emergency state (islanded) operations.
3. The difference between a Microgrid and a passive grid penetrated by micro-sources lies mainly in the way of management and coordination of available resources. [5]
\[ N_g = \text{generator efficiency (50\% for car alternator, 80\% or possibly more for a Permanent magnet generator or grid connected induction generator)} \]
\[ N_b = \text{gearbox/bearings efficiency (It could be as high as 95\%)} \]

**D. System settings for the fuel cell system part**

A fuel cell system is engaged as a backup generator in the selected micro-grid power system while a diesel engine generator is commonly used as a backup generator in micro-grid power systems. The output power of the fuel cell system is assumed a constant as 200kW for its operating range.

**VI. SIMULATION RESULT**

In the Photovoltaic Generation part, the total cumulative Power a day is about 1,698 kWh from the Figure 8. It means that the photovoltaic generation system can only cover less than 4 hours from the Figure 9.

![Figure 8. Total cumulative power from photovoltaic generators](image1)

In Wind Turbine generation part, the cumulative power a day is 1936 kWh from the Figure 10. However, this micro-grid power system requires more than 4,800 kWh power a day according to simulation setting. In other words, wind turbine generators can only cover the given load size for 6 or 7 hours from Figure 11. As a result, the wind turbine system which has 9 wind turbine generators is not enough to satisfy the load in the micro-grid power system.

![Figure 10. Total cumulative power from wind turbine generator](image2)

When integrating solar and wind together, it only covers about 20 or 21 hours as shown in Figure 12. Therefore this combination of the wind turbine system and the photovoltaic system is still unable to provide required power to this micro-grid power system. The result of the entire micro-grid in which photovoltaic, wind and fuel cell are integrated is shown in Figure 13.

![Figure 11: Remained power in battery when wind turbine System and 200Kwatt load are working](image3)

![Figure 12: Battery condition when Microgrid system is working with both PV and wind turbine system](image4)
VII. CONCLUSION

The paper reviews the energy generation capacity of eco-friendly energy resources using matlab in microgrid and we can conclude that only wind power or only solar power is not sufficient to meet the load demand. So we can use both the system combine with battery backup and with fuel cell. After integrating 3 renewable resources together we get sufficient energy to consumer. Research is still on in this direction and in future this battery bank power is inverted to feed the grid. Number of technical challenges and problems are identified and listed in integrating microgrid with the main grid are included. Using modeling of the renewable sources, microgrid can be simulated for the problems identified.

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