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Integrated System Design that Produces Electricity with Solar, Wind, Hydrogen and Biomass Energy

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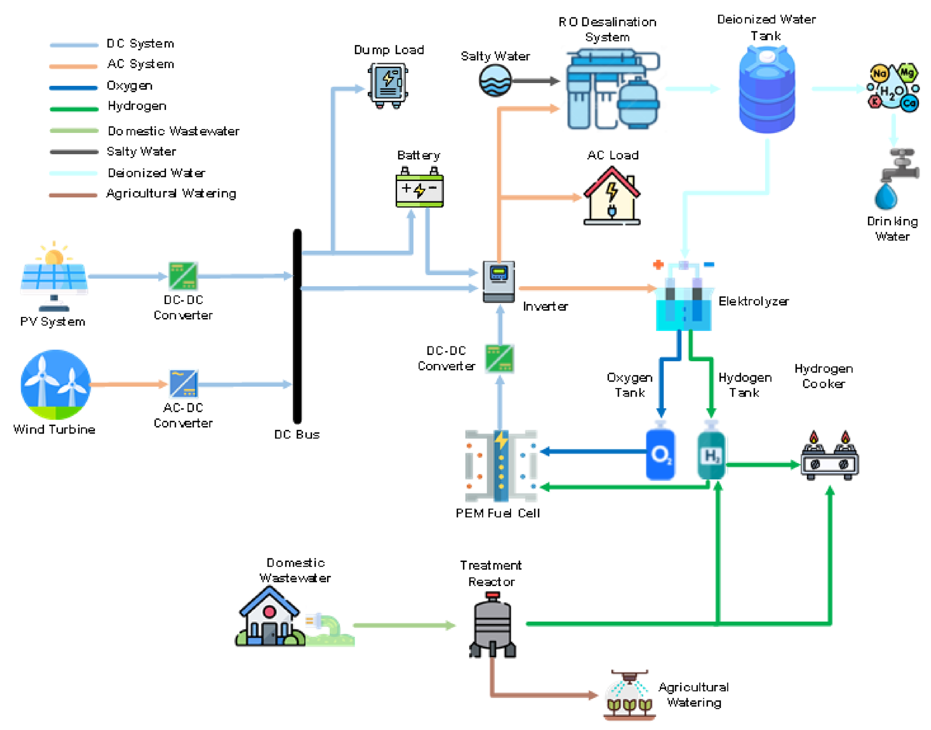
I. Introduction

Humans have been using fire to produce heat and light for thousands of years. In the mining ages, many materials, from primitive kitchen utensils to hunting weapons, were made by melting metals. With the Industrial Revolution, fire was used in the development of more advanced systems. In this period, when there was no option other than fossil fuels for energy production, all steam-powered vehicles and factories were powered by coal or wood. Today, fossil fuels still dominate industry, energy, and transportation. Fossil fuels, indispensable and progressive carriers of human civilization for approximately 170 years, are now causing events that negatively change the planet's climate and whose consequences are visible. Greenhouse gases such as CO2 and CH4, which occur due to the use of fossil resources, prevent the sunlight reflected from the surface from passing from the atmosphere to space, causing surface temperatures to increase. Between 1880 and 2012, the global average land and ocean surface temperatures increased by 0.85 °C to 1.06 °C [1]. This study aims to design a system that will meet the electricity and clean water needs with solar, wind, hydrogen, and biomass energy. Hydrogen energy in the system will be produced in two ways: green hydrogen in the electrolyzer and biohydrogen in the wastewater treatment reactor. In the anaerobic fermentation process carried out with different microorganisms, wastewater treatment, and hydrogen production will be carried out.

II. Hybrid System Design

In this study, a PV system, wind turbines, and PEM fuel cells will be used to produce electricity, an electrolyzer and purification reactor will be used to produce hydrogen, and an Reverse Osmosis device will produce clean water. Compared to distributed energy systems, a schematic representation of a self-sufficient integrated system that produces clean water and purifies wastewater is given in Figure 1. Auxiliary elements such as power switch, sensor, regulator, valve, and compressor are not shown in the figure.

To determine the PV system, wind turbine, PEM fuel cell, and battery to be used, firstly, 2021 annual solar and wind energy data were obtained for the Elazığ province Fırat University, Department of Electrical and Electronics Engineering location (38.675 N, 39.187 E) [2]. Then, the power and energy values required by the loads must be determined. The power values and usage times of the domestic load group are given in Table 1.



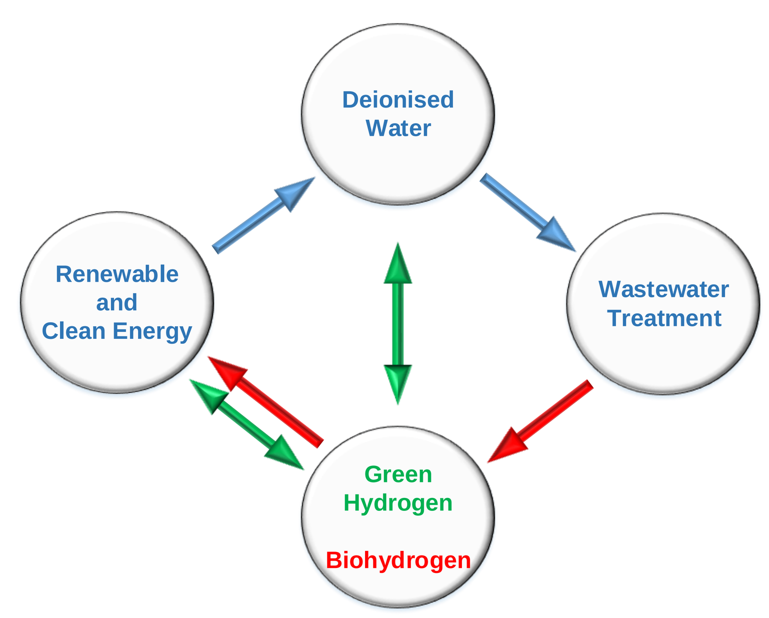


Figure 1. a) Hybrid system schematic diagram b) Relationship between systems

Table 1. House Load Profile

Device Name	Power (W)	Usage Time (Hour/Day)	Energy (Wh/Day)
Air Conditioning	600	4*	2400
Refrigerator	100	5*	500
LCD TV	100	4*	400
Laptop	100	4*	400
Lighting	100	7	700
Kettle	1000	0.2*	200
Total	2000		4600

III. Energy Management

In the system, the electrolyzer, RO device, domestic loads, and devices in the structure of IMS are considered electrical loads. The total energy produced in the PV system and wind turbines (EProduced) and the total energy consumed by the loads in the system (EConsumed) will be monitored instantly in the LabVIEW environment with data received from current and voltage transducers. The PEM fuel cell and battery group will not be activated when production is high. To prolong the life of the battery group, the State of Charge (SoC) value will be selected as a minimum of 40%. The PEM fuel cell and battery group will be activated if the production is lower than the requested energy. However, depending on the condition of the battery group and hydrogen tanks and the size of the energy difference, priority will be given to the PEM fuel cell. If the energy produced by the PEM fuel cell (EPEM) along with the PV system and wind turbines meets the consumed energy, only the PEM fuel cell will feed the load; if it is low, the battery group will also be activated. If the net energy is negative and there is not enough hydrogen in the hydrogen tank, the battery group will continue to feed the loads until it drops below 40% SoC. With the management system to be created, it is planned to keep the number of cycles of the batteries as low as possible. However, suppose the PV system and wind turbines do not produce energy for meteorological reasons or in the event of a malfunction. The PEM fuel cell and the battery will be activated in that case.

The commissioning of the PEM fuel cell will be decided by looking at the data from the pressure sensor in the hydrogen tanks. If the pressure value drops below 4 bar, the fuel cell will be disabled. In this case, the requested energy will be met by allowing the SoC value of the battery group to drop below 40%. As long as the pressure value is higher than 4 bar, the SoC value will be kept at a minimum of 40%.

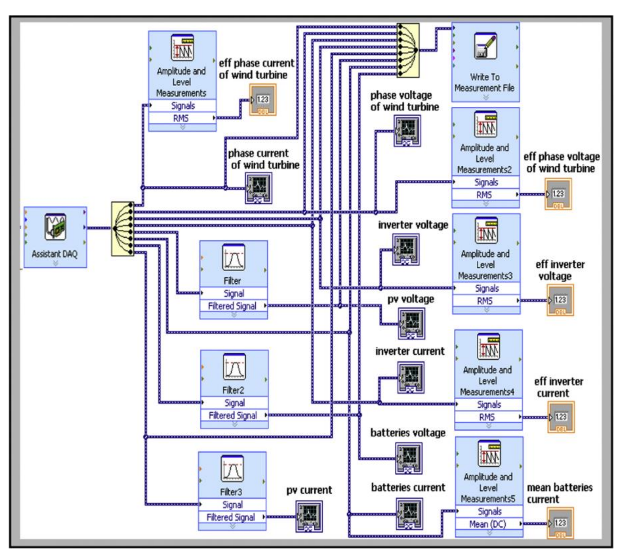


Figure 2. LabVIEW energy management block diagram [3]

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