COMET: A combination of multiple-energy technologies - Another alternative to renewable energy, based on solar energy and hydrogen fuel for effective irrigation in drought-stricken Indian regions.

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ABSTRACT

Hydrogen power has a high recommendation over low carbon and purity, high energy density, and efficient conversion; expected to play an important role in India. It analyzes the research status and prospects for the development of various technologies in hydrogen production, hydrogen storage, and hydrogen utilization. On this basis, specific technologies are proposed for the development of renewable energy and integrated hydroelectric resources. Solid polymer electrolyte (SPE) electrolysis for hydrogen production and solid hydrogen storage materials is a potential development in the direction of hydrogen production and hydrogen storage. Technologies such as hydrogen fuel cell and hydrogen gas as fuel for the 4-stroke IC engine interface should be developed simultaneously. The production of hydrogen gas from a photovoltaic grid capable of generating fuel cell power and internal combustion 4-stroke engine technology can effectively solve the dependence on renewable energy. At the same time, hydrogen energy can detect the connections of multiple energy networks, and the prospects for its future use in integrated energy service parks are much broader. This system will not only be used for irrigation without interruption but will also be used to meet the needs of the home load without the grid.

INTRODUCTION

The widespread use of fossil fuels has brought about a variety of environmental, ecological, and global climate changes [1]. Large-scale implementation of periodic renewable energy. Systems need to close the temporary and space gap between supply and demand [2]. Reducing fossil fuels has been strongly suggested under international frameworks, including the Sustainable Development Goals (SDGs) and the Paris Agreement [2]. Increasing the use of renewable energy sources (RES) in energy mixing has become a challenge for energy engineers and scientists around the world. Although mixed energy systems based on RES (HRES) have attracted the attention of a sustainable energy market, efficient use of solar photovoltaic (PV) or wind power is difficult, especially for local power grids [3]. This is due to their flexible nature and intervals, due to their dependence on weather conditions. Thus, independent renewable energy sources cannot guarantee reliable power supply. A common solution to this problem is the use of HRES to combine both short-term energy storage options (batteries, capacitors, flywheels, or compressed air) and long-term hydrogen-like power storage [3]. With nearly 1.3 billion people in the world (or about 1 in 5) without electricity in 2010, the challenge of providing reliable and affordable services remains the biggest global challenge facing the world in this century [4]. Although the expansion of the grid is still the preferred method of expanding the rural grid of medium-to-low rural grid may not be financially viable or not at all [4]. Off-grid options can be helpful in such situations. In addition, efforts to use renewable energy are often focused on a single technology [4]. For example, Solar Home Systems (SHS), solar photovoltaic systems and micro-hydropower have been widely used, but such options are often incapable of providing consumer needs adequately and reliably due to limited-service availability resulting from diversity of resources [4]. Reliance on a single technology often leads to an increase in system size, thus increasing initial costs. The hybrid system design can overcome the temporary environment of renewable energy sources (RES), the problem of excessive size and improve the reliability of the supply.

However, mixed systems have received limited attention due to their complex growth and almost no work has ever considered the issue of reliable electricity supply in rural areas [4].

In remote rural areas, the need for electricity can be met using HRES, but their introduction has reduced the lack of economic efficiency and technological adaptation. Air power lines, which are very expensive, are often extended to natural areas to distribute electricity for sale to consumers. These infrastructures have a detrimental effect on the environment and, more importantly, kill native and migratory birds, a critical issue in the case of endangered species [3]. Among the various renewable resources, photovoltaic power generation (PV) is reported to have the greatest potential. To improve the usability of PV, a number of methods have been tested, especially under power-to-X concepts [2]. Power-to-gas and power-to-liquid can be key components in a sustainable future energy system that includes electricity, mobility, heating, and chemical fields. Power-to-gas has become a major technology for converting electricity into gas, especially with hydrogen as an energy carrier, which is one of the most important options for sustainable hydrogen production [2]. Irrigation systems, in rural and arid areas of India with poor access to grid electricity, are limited to diesel generators. The diesel-based irrigation system is a major cause of climate change, depletion of fuel depots, rising operating costs and diesel, maintenance problems that encourage the search for alternative energy system [5]. Currently, solar PV irrigation system is considered a separate irrigation solution. Demonstrates economic, environmental and technological efficiency over a diesel-based irrigation system. Currently, the battery storage system is not included in the solar irrigation system in India due to its high cost and maintenance problem. And the importance of energy conservation should be considered in times of great need and adverse weather conditions. Indeed, in the case of long-term energy storage, it is best to use an efficient, effective and reliable hydrogen system. Hydrogen production in water will gradually replace fossil fuels and become a major energy carrier in the second half of the 21st century. Water is often regarded as a stable and pure source of hydrogen production, especially when the term renewable energy is used [5]. The hydrogen fuel-based irrigation system is a different solution to meet the current agricultural needs instead of pressuring the Indian economy. This is another solution that will work effectively and be environmentally friendly. A straight couple of DC water pumps with a solar system where the converter and storage can be used for irrigation have been evaluated effectively and efficiently. In India, moderate irrigation is required 3 to 5 hours a day for cultivation and the sun's rays are available for 7 to 8 hours. About 50 percent of the sun's rays are used to power the load. The use of 50% of unused radiation by any storage system can not only reduce the size of the solar panel but also reduce the earth used to set the solar panel. Therefore, farmers can use a lot of land to farm. In this paper, a DC pump is selected to design and mimic a hydrogen-based fuel cell irrigation system in India. This study was conducted using the development tool: HOMER pro (Hybrid Optimization of Multiple Energy Resources) simulation software for the economic development model test model, which reduces energy production costs to meet the ultimate energy requirement on a net basis. current costs. Thus, HOMER based hydrogen fuel cell irrigation system is analyzed and designed as a renewable green energy technology by reducing the energy storage requirement, improving efficiency and reliability [5].

Nomenclature

Symbol	**Abbreviation**	**Symbol**	**Abbreviation**
SDGs	Sustainable development goals	AC	Alternating Current
RES	Renewable energy sources	DC	Direct Current
HRES	Hybrid power system based on RES	FC	Fuel Cell
SHS	Solar home System	V_1/V_2	Compression Ratio
PV	Photovoltaic	γ	Specific heat ratio
HOMER	Hybrid Optimization of Multiple Energy Resources	T_1 T_2	absolute initial & final temperature
NREL	National Renewable Energy Laboratory, USA	H2FC	Hydrogen and Fuel cell
RE	Renewable Energy	H_2	Hydrogen fuel
PEMFC	Polymer electrolyte fuel cell	PEM	Polymer Electrolyte Membrane
KWh	Kilo watt hours	KVA	Kilo volt amperes
Backup Production	Hydrogen gas combustion in 4-stroke IC engine couple with 5KVA alternator to produce AC.	NPC	Net present Cost
COE	Cost of Energy.	COMET	Combination of multiple energy technology.
Fig.	Figure		

2. Literature review

The motive of the literature evaluation supplied here is twofold: first, this offers evidence of understanding hole that justifies the need for these paintings; and 2d, it additionally presents a guide for the technique used in the take a look at and is a supply of information for assessment, triangulation and referencing. Given the above cause, we use the literature to reveal the constraints of present studies through focusing especially on studies that trusted HOMER because of the analytical tool. HOMER (Hybrid Optimization Model for electric-powered Renewables), advanced via NREL (national Renewable power Laboratory, USA) seems repeatedly in the literature as a desired tool [4]. it could deal with a big set of technologies (inclusive of PV, wind, hydro, fuel cells, and boilers), masses (AC/DC, thermal and hydrogen), and can perform hourly simulations. HOMER is an optimization tool this is used to decide the gadget configuration for decentralized systems. it has been used both to analyze the off-grid electrification troubles in the developed as well as growing countries. in the case of developed international locations, frequently advanced gasoline systems together with hydrogen are taken into consideration. For developing international locations, a huge wide variety of research exist and a detailed evaluation of this literature is beyond the scope of this paper. rather, we are aware of a selected set for our reason. through a huge number of simulations, the observe observed that the PV-hydrogen fuel becomes cost-powerful because the demand increases. however, this examination focuses on the fundamental wishes as such and does now not encompass effective use of energy. The cost of power from gas cellular-based totally electricity generation against the fee of delivery from the grid for a rural hospital in India, making use of HOMER simulations. The consequences showed beyond a distance of forty-four km from the grid, the price of supply from an off-grid supply is less expensive. These paintings just considered the demand of a rural sanatorium and turned into not part of any traditional rural electrification program. it has been analyzed that the gold standard design and making plans of renewable power-based micro-grid gadget for a hypothetical rural community in which the base load is six hundred kW and the height load is 1183 kW, with an everyday electricity requirement of 5000 kWh/day. The observation considers sun, wind, hydro and diesel sources for power generation. even though they take a look at considering electricity calls for over 24 h, the basic terms and hypothetical nature of the assumptions make the work unrealistic for plenty off-grid areas of developing countries. The look at uses a hypothetical case of irrigation of one Hectare land with a peak call of 5-7 kW. it can be seen that the hybrid alternatives have often taken into consideration a confined set of technologies. moreover, maximum studies concentrate on presenting energy merely for home purposes and do no longer recall the electricity demand for agricultural, irrigation, community functions and for small-scale enterprise units for the socio-monetary development of the entire region. the load profiles are also now not cautiously considered in many cases. these troubles are considered within the present observation, thereby bridging the understanding gap.

The social attractiveness of renewable power (RE) infrastructure plays a critical position in the furtherance of the RE transition and social science research facilitates a better understanding of the elements that affect the attractiveness and expansion of such technologies. at the same time as much, preceding research are targeted renewable sources of fuels and power which include ethanol, wind, and hydro and aren't particular to solar, they may be nonetheless broadly relevant, emphasizing power improvement as a social count with technical components as opposed to a technical count with social components [6]. The three-dimensional social popularity framework movements past designations of humans as simple supporters or warring parties and recognizes that the acceptance of RE is a complex social response. paintings are primarily based on hydrogen gas and renewables in trendy, the constructs developed are carried out here to agrovoltaics because of the similarities between huge tracts of agricultural land being appropriated for sun strength generation. As new strength technology inclusive of agrovoltaics goes beyond the area of interest applications to grow to be extra well-known, the dimensions of social attractiveness, inclusive of the possibilities and barriers related to each dimension and their interconnections, can help inform choice-making to decorate the growth of agrovoltaic development [6]. the latest research maintains that the social dimensions of developing energy structures are possibly the maximum vital, as preceding endeavors in India reveal that the social aspect of development can ultimately determine the fulfilment of a sun task. The paradoxical social gap describes excessive public assistance for hydrogen fuel but low fulfilment for concrete local traits, highlighting a discrepancy that is restricting the proliferation of RE [7]. Public opinion surveys were performed to verify this social hole in regards to solar power, finding robust Indian aid for large-scale sun yet eminent opposition to neighborhood tasks. the overall superb mindset towards the sun has efficaciously misled applicable actors to miss social popularity as an invaluable detail of development similarly widening the distance between challenge notion and ultimate implementation. because social recognition is pivotal to energy transitions, this examination reflects a proactive attempt to recognize agrovoltaics from a solar industry expert’s angle to better understand the opportunities and limitations of agrovoltaic systems; the responses centered on issues associated with social reputation and public perceptions, consequently this paper places the findings from this research into the context of social reputation framework.

2.1. Market dominance

The market size of renewable energy adoption includes market acceptance and adoption of technology by consumers, investors, and firms. The growth of RE-founding depends on how technology enters the market and stimulates investment and that business-related issues and types of revenue, including local decisions, play an important role in the acceptance of various market players. From an investor's point of view, reliability of RE technology is critical to its implementation. However, the lack of reliable information for participants is understood to be a very common obstacle to market acceptance. To investigate situations that promote market acceptance, three key factors are important: competitive costs of installation / production; methods of obtaining information and feedback; and access to financing.

2.2. Community adaptation

By building on the importance of the RE environment context, research has turned to addressing social resistance and geographical conflicts. Numerous studies have shown that the successful implementation of RE programs requires sensitivity to local community preferences and values. Research focused on the RE community side finds that local support is the most important factor in making projects real. Research has found that location-based factors have a significant impact on community perceptions and attitudes. Therefore, consideration and acceptance of community preferences and values is the result of gaining public acceptance of a solar space project. However, it is found that rural residents see hydrogen fuel and irrigation based on solar energy as an opportunity to protect their farming environment in other uses, thus preserving rural ownership. Without the support of rural landowners and farmers, large PV will be severely limited and the successful implementation of agrovoltaic systems will depend on the farmer 's acceptance. Because solar projects representing local communities are expected to have high levels of acceptance, it will be important that the design and scale of agrovoltaic systems are aligned with rural ownership and interests [6].

2.2.1. Stakeholder participation

Within the realm of social acceptance, stakeholder engagement and participatory decision-making are well-recognized strategies that contribute to high levels of acceptance and successful RE development. Asking for public participation effectively ensures that local voices are heard, considered, and included in the project, giving developers a direct opportunity to demonstrate local priorities in RE development. Observing the principles and principles of the community, both better understood and managed through public participation, is more important and strategic, as a collectively designed system allows for local acceptance rather than resistance. Consideration of all stakeholders involved in organizing participatory capacity may contribute to the creation of a project that generates local benefits: the financial benefits from the RE project remain social and a sense of solidarity and pride often matures among citizens [6].

2.3. Socio-Political approval

The socio-political dimension of acceptance includes policy makers and key stakeholders. Research on the socio-political acceptance of FE has sought to understand this dimension, using both public opinion surveys aimed at measuring factors influencing support for FE and research on government policies and incentives. Policies that provide financial incentives lead to greater social acceptance of solar energy, especially if host communities benefit most [8]. The implementation of solar energy is ultimately a local political decision, as municipal governments and zoning boards involve members of the relevant community and provide a forum to include public views, so an awareness that solar projects work in the context of a local policy is essential for successful development. Applying these research findings to the emerging agrovoltaic concept requires investigating how policy measures, public engagement models, and social institutions can help promote social acceptance of such developments [6].

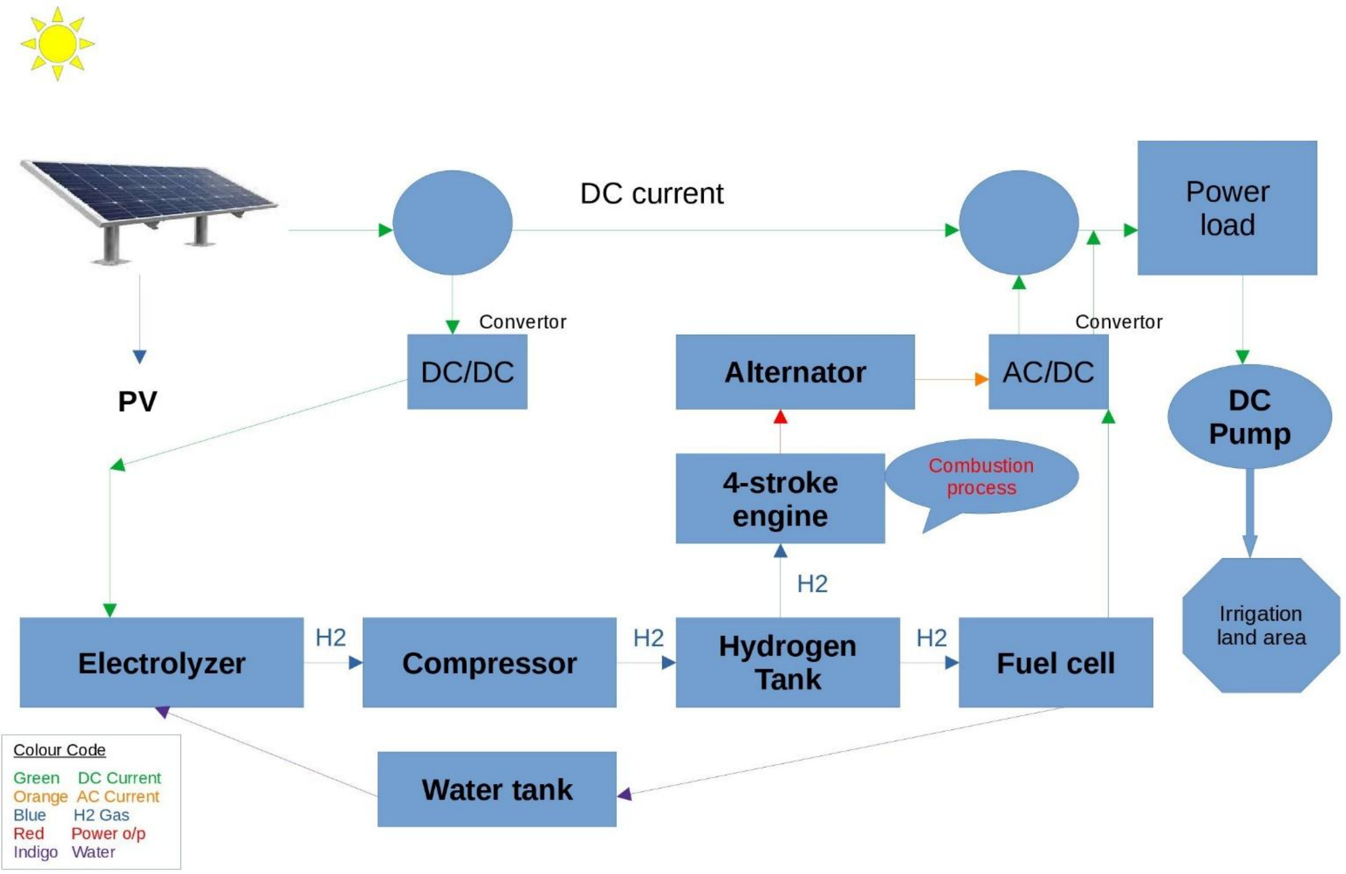

Fig.1 The proposed Hydrogen based Irrigation system

3.System Description

The schematic system shown in Figure 1 below can be divided into four subsystems: solar photovoltaic (PV) system, fuel cell (FC) system, DC submersible Pump and 4-stroke IC engine backup. Solar photovoltaic system and 4-stroke IC engine with alternator is the main system that generates electricity to meet the electric load demand by converting solar energy into direct current electricity. Before sending electrical power to the load, an AC/DC converter is required to obtain DC[9].

The proposed fuel cell system can be divided into four specific stages: (1) hydrogen generation stage, (2) Hydrogen storage stage (3) Backup stage (4-stroke IC engine) and (4) use stage.

The hydrogen production cycle will begin in the electrolyzer, where water will be converted to hydrogen using electricity from photovoltaic modules. This hydrogen will be compressed and stored in steel composite tanks. When necessary, hydrogen will be sent to the fuel cell and 4-stroke IC engine for combustion, which will produce the demanded electricity [3]. The hydrogen produced is stored in a hydrogen tank. Hydrogen storage will play an important role when the weather is unsuitable, overnight or when demand exceeds the capacity to generate electricity from the PV system. This stored hydrogen will be supplied to the fuel cell (FC) which will generate electricity to fully meet the demand via a DC/DC converter, as in the electrolyzer, in this case to increase the voltage. In order to minimize water consumption, the water produced by the fuel cell is stored in a water tank, and water is supplied from the tank[9] when the electrolyzer needs it. Apart from all these stages, in case of failure of the above-mentioned power supply for any reason that may cause technical or physical damage, an additional backup, that is, a 4-stroke IC engine with hydrogen gas burning, is provided in the system for uninterrupted irrigation. It will provide braking power output to the connected alternator which will generate AC current. This AC current will be converted to DC current through the AC/DC converter to drive the DC submersible pump.

In use, hydrogen is fed into the fuel cell to generate electricity to drive the DC Submersible Pump to lift water. The entire stage and process is shown in Figure 1. Storage hydrogen will play a leading role at night or in any system failure. In this role, the stored hydrogen will feed the fuel cell, and the fuel cell will use this hydrogen to generate electricity that will fully meet the irrigation water demand [5].

2.1 Hydrogen as a fuel

Due to the following properties of hydrogen which contribute to its use as a fuel:

- wide range of flammability
- low ignition energy
- small quenching distance
- high self-ignition temperature
- high flame speed at stoichiometric ratios
- high diffusivity
- very low density [10]

➢ Wide range of flammability

Hydrogen has a broad flammability range than all other fuels. As a result, hydrogen can be burned in an internal combustion engine on a wide range of air-fuel mixtures. A significant benefit of this is that hydrogen can run on a lean mixture. A lean mixture is one in which the amount of fuel is less than the theoretical, stoichiometric or chemically ideal amount required for combustion with a given amount of air. This is why it is quite easy to start a hydrogen engine [10].

➢ Low ignition energy

Hydrogen has a very low ignition energy. The amount of energy required to ignite hydrogen is about an order of magnitude less than that required for gasoline. This allows hydrogen engines to ignite lean mixtures and ensures prompt ignition [10].

➢ Small quenching distance

Hydrogen has a small extinguishing distance, shorter than gasoline. As a result, the hydrogen flames move closer to the cylinder wall than other fuels before extinguishing. Therefore, it is more difficult to put out a hydrogen flame than a gasoline flame. The shorter extinguishing distance can also increase the tendency to backfire as the flame of a hydrogen-air mixture passes more easily a nearly closed intake valve than a hydrocarbon-air flame.

➢ High self-ignition temperature

Hydrogen has a relatively high self-ignition temperature. This has important implications when a hydrogen-air mixture is compressed. In fact, the auto-ignition temperature is an important factor in determining what compression ratio an engine can use, as the temperature rise during compression is related to the compression ratio. The temperature increase is shown by the equation:

$$T_2 = T_1\left(\frac{V_1}{V_2}\right)^{\gamma-1} \qquad (1)$$

where is it:

V1 / V2 = the compression ratio
T1 = absolute initial temperature
T2 = absolute final temperature
γ = ratio of specific heats

The temperature cannot exceed the hydrogen self-ignition temperature without causing premature ignition. Therefore, the absolute final temperature limits the compression ratio. The high self-ignition temperature of hydrogen makes it possible to use higher compression ratios in a hydrogen engine than in a hydrocarbon engine [10].

➢ High flame rate

Hydrogen has a high flame rate at stoichiometric ratios. Under these conditions, the flame velocity of hydrogen is almost an order of magnitude higher (faster) than that of gasoline. This means that hydrogen engines can get closer to the thermodynamically ideal engine cycle. With leaner mixtures, however, the flame speed decreases significantly [10].

➢ High diffusivity

Hydrogen has a very high diffusivity. This airborne ability is considerably greater than gasoline and is beneficial for two main reasons. First, it facilitates the formation of a uniform mixture of fuel and air. Second, if a leak of hydrogen develops, the hydrogen is rapidly dispersed. Therefore, unsafe conditions can be avoided or minimized [10].

➢ Low density

Hydrogen H has a very low density. This results in two problems when used in an internal combustion engine. First, a very large volume is required to store enough hydrogen to provide a vehicle with adequate driving range. Secondly, the energy density of a hydrogen-air mixture is reduced, and therefore the power output [10].

3.2 Hydrogen infrastructure

The development of the hydrogen infrastructure is a major obstacle to the widespread adoption of H2FC technologies. There is a perception that an all-encompassing "hydrogen economy" must be established with enormous costs and duplication of existing energy infrastructure. Developing a cost-efficient infrastructure from these options that can evolve over time as demand develops is a significant challenge. Centralized production methods based on new distribution networks, synonymous with a vision of the hydrogen economy. There are also incremental and less infrastructural pathways, which use existing gas or electricity networks and reduce large upfront costs, albeit at the expense of lower efficiency. Indeed, H_2Mobility concluded that just 100 small fueling stations with on-site hydrogen production would be enough to supply the majority of India's population in the early stages of the transition to fuel cell vehicles, with additional infrastructure implemented as demand increases. This suggests that infrastructure development may not be as challenging as some have suggested.

4. Methodology

The system was proposed to continue the supply of electricity to the irrigation sector through unconventional sources. The methodology of this project was developed to design hydrogen fuel cell and hydrogen gas as a fuel for 4 stroke internal combustion engine system using HOMER in Fig. 2, the procedures are discussed below:

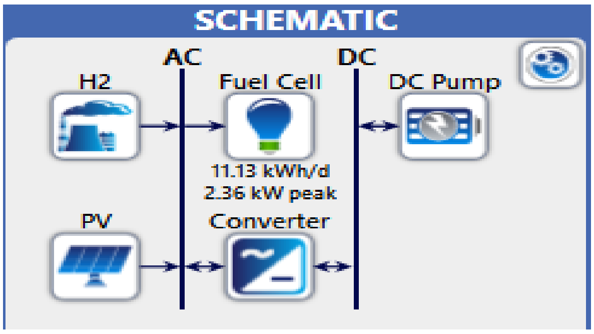

Fig. 2. DC pump-based irrigation in HOMER PRO

4.1 Experimental study of the system

The proposed system is designed for the whole national territory, in particular for those areas where most of the irrigation depends on the diesel pump or the connection to the grid. Here solar energy is used for electrolysis of water to produce hydrogen which is further used to run the fuel cell to power the submersible DC pump to pump ground water for irrigation and in other cases if failure occurs, as backup hydrogen gas produced by electrolysis the process will be used to run a 4 stroke internal combustion engine which would be coupled with a 5KVA alternator which will be converted to DC via a converter and used to drive a submersible DC pump for continuous irrigation. Irrigation depends on rainfall, soil characteristics, local climate and crop characteristics. Depending on India's weather conditions, irrigation is required from January to May and from October to December. India's average monthly rainfall is described in Table I [11]. On paper, 8,60,000 liters / hectare of average water per month are needed for rice, wheat, cotton, peanuts, vegetables, etc. The running time of the system is considered 3-7 hours for the calculation but the time is not limited, it would vary season by season. Hence, whenever water is needed, it is enough to supply.

Month	*mm*	*L/Hectare*	*Month*	*mm*	*L/Hectare*
JAN	*13*	*1,30,000*	*JUL*	*307*	*30,70,000*
FEB	*13*	*1,30,000*	*AUG*	*258*	*25,80,000*
MAR	*17*	*1,70,000*	*SEP*	*162*	*16,20,000*
APR	*12*	*1,20,000*	*OCT*	*75*	*7,50,000*
MAY	*55*	*5,50,000*	*NOV*	*17*	*1,70,000*
JUN	*92*	*9,20,000*	*DEC*	*11*	*1,10,000*

TABLE I Precipitation in INDIA[12]

4.2 Selection of DC Pump

For this project, a 1.1 kW submersible DC solar pump was selected which has a flow rate of 55 LPM with 20 m water height and the solar pump can lift 3300 l / hour at rated output [13]. Five hectares of sample land were taken to irrigate for the hypothetical system project. The monthly average daily water pumping load can be calculated using formula (1) which incorporates the amount of precipitation [14].

$$L = \frac{W_c - W_p}{30(F_p \times 60)} \tag{1}$$

where L is the average daily monthly water pumping load (kWh / day). WC is the monthly water needed for crops (liter / hectare / month). Wp is the average monthly precipitation (liters / hector / month) and FP is the pump flow rate (liters / min or LPM). The average annual load profile is illustrated in Fig. 3 calculated with formula (1); irrigation is maximum required in the dry season (November-March) as used in the HOMER PRO study as shown in Fig. 4. Here the annual average is 4,186 kWh / day and the annual peak is 1542 kWh / year [15].

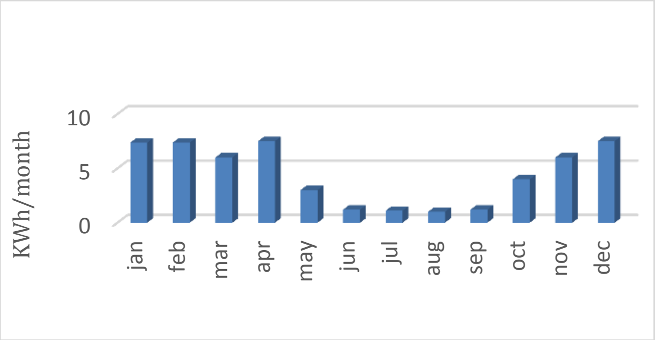

Fig. 3. Monthly averaged load DC submersible pump

demand for work. At 350 bar and 500 bar, this deviation is 4 and 9% more than what is required by the ideal gas law. By evaluating the work required to compress hydrogen, we should compare it with the specific energy content of hydrogen, 33 kWh kg − 1. In this context, about 10% of the available work is dedicated to the compression of hydrogen up to 500 bars.

In order for this system to work efficiently, we are introducing a hydrogen membrane compressor, which is a reciprocating compressor that reciprocates in a cylinder to compress the gas. Diaphragm compressor is a special type of volumetric compressor with a large compression ratio, good sealing performance, and the compressed gas is not polluted by lubricating oil and other solid impurities. Therefore, it is suitable for compressing high purity, rare and precious, flammable, explosive, toxic and noxious, corrosive and high-pressure gases. It has a special name as it has a special diaphragm that separates the compressed medium from the outside. The diaphragm compressor can also be referred to simply as a diaphragm compressor. Due to its special structure, the reciprocating oxygen low pressure diaphragm compressor does not need lubrication and the sealing performance is very good. The compressed medium is not in contact with any sliding agent, so it can compress the gas with a very high purity, generally reaching a purity of 99.999%, which is more suitable for compression. In addition, membrane compressors are also particularly suitable for corrosive, radioactive, toxic and explosive gases. The diaphragm compressor has good heat dissipation and can adopt a high compression ratio, so its pressure range is wide and the discharge pressure can go up to 500MPa. It is used in the food industry, the chemical industry of the petroleum industry, the electronics industry, nuclear power plants, aerospace, military equipment, medicine, scientific research and other fields [23].

Fig 7. Nova Swiss MK-Diaphragm Compressor

4.6 Hydrogen Tank

Storing hydrogen in compressed gaseous form offers the simplest storage solution. A fixed energy storage system is necessary to meet the load demand when the energy produced is insufficient. The hydrogen gas storage system has an economic and technical advantage over the battery storage system for long-term storage. Compressed hydrogen is mainly stored in cylinders with hemispherical caps, similar to those used for the storage of natural gas and other process gases [24]. The connection between the hydrogen storage tank and the fuel cell is internal in HOMER PRO. In this system, the hydrogen accumulation acts as a backup of the system during the non-operation of the photovoltaic system or in the event of another technical failure. In the event of a photovoltaic or non-functioning failure, the hydrogen gas from the storage will be injected through the nozzle into the 4-stroke IC engine where the combustion process rotates the alternator shaft which confirms the output for the submersible DC pump. which ensures uninterrupted power supply to the system and governs the continuous irrigation process. A schematic of a hydrogen storage tank is shown in figure 8. Here we are using the storage of a 10 kg (net weight of hydrogen gas) cylinder from the goggle manufacturer Gemini [25].

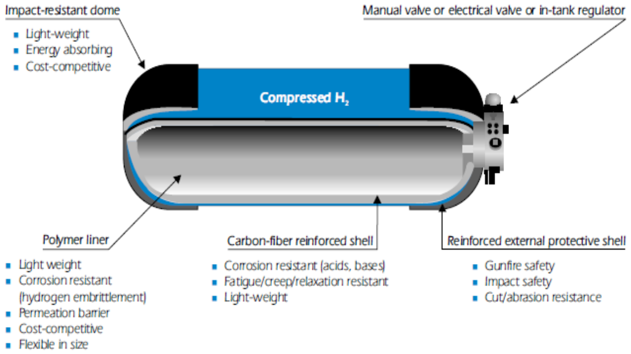

Fig. 8 Schematics of Hydrogen storage tank

4.7 4-Stroke IC Engine

An efficient parallel system is designed to act as a backup for the COMET which includes the combustion of hydrogen in a 4-stroke IC engine. For this, we use a 196cc 3-liter 4-stroke engine from VED firms which would be modified by a disc-shaped combustion chamber (with flat piston and chamber ceiling). The most challenging part of burning hydrogen in an IC engine is checking the pre-ignition and knocks. However, to solve this problem, we have to redesign the engine, especially the combustion chamber and the cooling system. A disc-shaped combustion chamber (with flat piston and chamber ceiling) can be used to reduce turbulence within the chamber. The shape of the disc reduces the radial and tangential low velocity components and cancels the amplification of the input vortex during compression. Since unburned hydrocarbons are not a problem in hydrogen engines, a large bore / stroke ratio can be used with this engine. To accommodate the wider range of flame speeds occurring over a wider range of equivalence ratios, two spark plugs are required. The cooling system should be redesigned to provide uniform flow to all places that need to be cooled. At the same time, second measures can be used to decrease the probability of pre-ignition by applying two small exhaust valves instead of a single large one, which develops an effective evacuation system, through which the exhaust gases of the combustion chamber will be replaced with fresh air. Here in fig 8, the combustion chamber of the 4-stroke engine will be modified with the flat piston disc chamber as shown in fig 9.

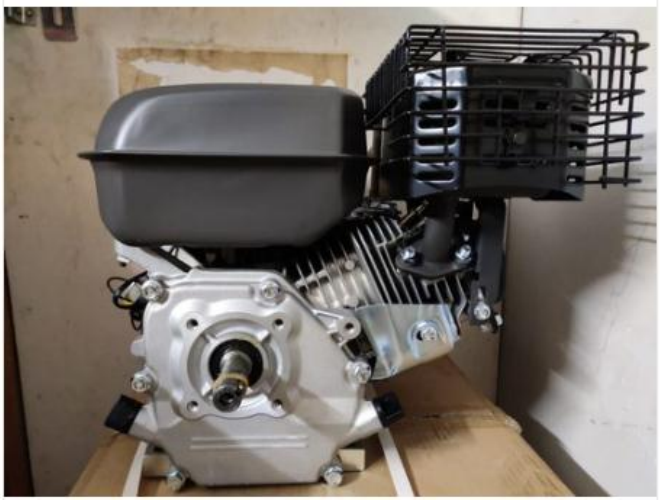

Fig. 9 4-stroke IC Engine.

Fig. 10 Modification of 4-stoke IC engine combustion chamber

4.8 Alternator

An alternator is an electrical generator that converts mechanical energy into electrical energy in the form of alternating current. For reasons of cost and simplicity, most alternators use a rotating magnetic field with a stationary armature. Occasionally a linear alternator or rotating armature with a stationary magnetic field is used. In principle, any AC electric generator can be called an alternator, but usually the term refers to small rotating machines powered by automotive engines and other internal combustion engines. An alternator that uses a permanent magnet for its magnetic field is called a magneto. Alternators in power plants driven by steam turbines are called turbo-alternators. Large 50 or 60 Hz three-phase alternators in power plants generate most of the world's electricity, which is distributed by power grids. Here In our system, we are using a 5KVA alternator from Ayush electric company, as shown in figure 10, which would be coupled with a 4 stroke IC motor to produce AC and be converted to DC to run the main load for one. uninterrupted watering. However, it would run the compressor as well and then the main load of a compressor will be cut off and connected to this AC alternator.

Fig. 11. 5KVA Alternator

4.9 Solar Photo-voltaic cell

The Solar system is generally designed and sized to power electrical accessories in direct and / or alternating current. This consists of a connected photovoltaic solar module a solar charge controller, a converter or an inverter [9]. Solar panels generate energy from the sun by converting sunlight into zero-emission DC electricity that is supplied to an electrolyser that produces hydrogen gas. India is located between the latitude of 20.5937 ° North and the longitude of 78.9629 ° East [26]. The average global solar radiation is 6.50 kWh / m2 / day as the same monthly average solar radiation data in HOMER pro is shown in Fig. 11.

Fig. 12 Month- wise solar radiations

S.No.	Component	Manufacturer	Capacity	No.of Units
I	PV	Generic flat-plate PV	1KW	1
II	Electrolyzer	PEM Electrolyzer	1KW	1
III	Fuel Cell	Genset	2KW	1
IV	Compressor	Nova Swiss MK-Diaphragm Compressor	Up to 1000bar	1
V	Storage Tank	Gemini gases	10 kg	1
VI	4-stroke Engine (IC)	VED Enterprises	196cc	1
VII	Alternator	Ayush Electrical & power company	5KVA	1
VIII	DC submersible Pump	Rips Technology	1.1KW	1

Table. II System specification

S.No.	Parts	Production	Consumption
I	Electrolyzer(kg/year)	106	
II	Electrolyzer(KWh/year)		3100
III	PV(kWh/year)	4105	
IV	FC(kg/year)		61
V	FC(kWh/year)	1535	
VI	DC submersible pump (kWh/Year)		1924
VII	Alternator (kWh/year)	400	
VIII	4 stroke Engine (IC)(Kg/Year)		45
IX	Other Accessories		1016

5. Simulation and Result

The system is simulated in HOMER Pro by calculating the average demand, a different size of the combination of parts. The system is optimized for demand and load management. System specifications are shown in Table I.

In HOMER Pro, the design optimizes the system for 1 kW flat photovoltaic panels, 2 kW fuel cells, 1 kW electrolyser and 10 kg hydrogen tank capacity. Table III. shows the production and consumption of the entire system. According to the simulation result, the total electricity produced per year is 6040 KWh. The solar photovoltaic produces 4105 kWh / year and the fuel cells generate 1535 kWh / year and 400 kWh / year of reserve production (combustion of hydrogen gas in pairs of 4-stroke IC engines with 5 KVA alternator), which represent the 68%, 25% and 7% of the total production respectively.

Table III Simulated & Proposed Result of the overall system

The primary DC load of the system consumes 1535 kWh / year from fuel cells and 389 kWh / year more from backup production (combustion of hydrogen gas paired with 4-stroke IC engines with 5 KVA alternator). The photovoltaic output and backup production are used by the electrolyser to produce 106 kg / year of hydrogen gas. The average monthly electricity production is shown in Figure 13 by PV and FC.

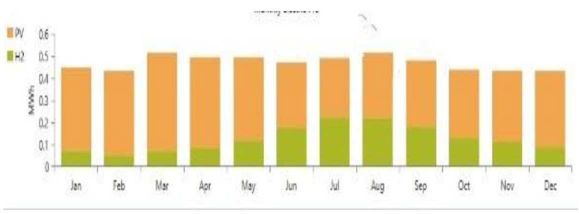

Fig. 13 Month-wise averaged power production by PV & FC

Figure 14 shows the annual hydrogen production and DC load consumption. 61Kg / year of pure hydrogen produced is used as fuel for a fuel cell which provides 1535 kWh / year of electricity to run the submersible DC pump. However, an additional production of hydrogen gas is also produced, i.e. 45 kg / year as a reserve (combustion of hydrogen gas in pairs of 4-stroke IC engines with 5 KVA alternator) for the continuous operation of the irrigation project.

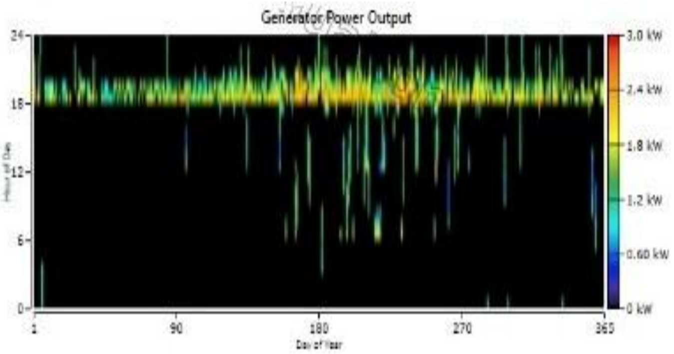

Fig. 14 Year-wise production of H2 & consumption of prime DC load

The net present cost (NPC) of the system is $ 5645 which is approximately 4.5 lakh rupees according to the Indian currency. The cost of energy (COE) is $ 0.0897 which is about 7 rupees per kWh according to the Indian system and the operating cost of this system is $ 17.6 per year which would be approx. 1,373 rupees respectively in Indian currency. The various costs of the system are shown in Table IV. The whole system is designed for the production of hydrogen in the field. Hence, there is the involvement of small transportation costs. The initial cost of the project is higher than the conventional diesel irrigation system, but a cost will be lower in 25 years due to the low maintenance costs. On the other hand, for a diesel irrigation system a diesel pump has a low initial cost but operation and maintenance costs rise every year due to the growth of diesel price. From the 2nd year of installation, diesel prices will rise 4-7% annually. The usual output of a diesel engine is about 3 kWh per litre of diesel. A 5-hectare area is considered for designing the proposed system and if the same system is designed for a diesel pump, it will consume 511-litre diesel and will emit 800 kgs of CO_2 per year. So, the per year fuel cost will be 577 $(45,006 Rupees) for a diesel-based irrigation system compared to the proposed system, the total cost (only for diesel) will be 14,425 $ (11.25 lakhs Rupees) for 25 years which is more than Net present cost (NPC) of Solar PV-Hydrogen Fuel Cell backup by hydrogen gas combustion in 4-stroke IC engine couple with 5KVA alternator System. Now if the cost of the diesel engine and per year maintenance cost are considered then it is clear that this designed system is less expensive than the diesel irrigation system[27].

Now let us compare with State grid electricity metered charges i.e., COE is 0.0897 $/kWh (7 Rupees/kWh). From table III total units utilized by DC submersible load i.e., 1924 kWh/year which cost around 172 $/year (13,468 Rupees/year). Now if we calculate the metered charges over 25 years with an inflation of 2-3% it would cost us 7500 $ (5.85 lakhs Rupees) which is much more than the Net present cost (NPC) of Solar PV-Hydrogen Fuel Cell backup by hydrogen gas combustion in 4-stroke IC engine couple with 5KVA alternator System. Now if the cost on grid state electricity metered charges to cost is considered then it is clear that this designed system is less expensive over on the grid state electricity metered irrigation system.

S. No	Parts ($)	Capital ($)	Replacement ($)	O&M ($)	Salvage ($)	Total ($)
I	Electrolyzer	1500	650		-410	1740
II	PV	1200	0	0	0	1200
III	FC	2000	0	350	-370	1980
IV	DC submersible pump	250	0	40	-35	255
V	Alternator	240	0	20	-80	180
VI	4-stroke Engine (IC)	150	0	30	-50	130
VII	Convertor	60	0	0	-10	50
VIII	Hydrogen Tank	110	0	0	0	110
	Overall System	5510	650	440	-955	5645

Table IV. Estimated Costing of overall the system

6. Conclusion

Compared to the existing system, the installation cost of the designed system is high but with the progressive development of the technology, the prices of the components used in the system will decrease in the near future. Furthermore, the operating and maintenance cost of the proposed system is very low and there is no significant replacement cost in 25 years of the project except for the electrolyzer. As a new phase of COMET renewable energy (combination of several energy technologies), through this document a hydrogen-based storage system is promoted for a wide use in every sector. Nowadays we see cooking gas, meaning LPG is now supplied through piping connection and a community is charged with metered rates that are much cheaper than LPG cylinders. So, in the same way, who knows that in the near future a wide use of gaseous hydrogen would require the same distribution system and would certainly reduce the dollars of the overall cost of the system [28]. This safe use of hydrogen gas expands the way it can be used for irrigation purposes in the agricultural sector rather than using a conventional battery storage system. Furthermore, the system operates at zero carbon emissions, however a very low amount of carbon emissions will evolve not directly from the system but indirectly due to the chemical reaction of atmospheric vapors [29]. Where conventional diesel systems or thermal power plants are in an alarming phase for carbon emissions. Hence, it can be said that COMET (Combination of Multiple Energy Technologies) would be a non- renewable energy alternative based on solar energy and hydrogen fuel for effective irrigation in drought prone states of India will be the unconventional solution for the next energy crisis.

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