Innovation of Reserve Generator with Hybrid System
By Cooperation between the Hydrogen Energy and Gasoline

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Abstract
The objective of this research is to develop the generator reserve with a hybrid system of cooperation between the hydrogen energy and gasoline. The generating capacity is 5 KW, 220 V and 1500 rpm. The highest hydrogen production yield is 0.46 liter per minute. The average electricity of hydrogen separation is 12.4 A. The average operation time of the generator by using 1 liter of oil without load is 48.01 minutes. The average operation time of the generator by cooperation between hydrogen and gasoline without load is 55.57 minutes. In addition, the experimental tests with 1000 W load found the only one fuel have 43.94 minutes of average operation time. However, the generator by cooperation between hydrogen and gasoline with 1000 W is 47.74 minutes. The economic assessment found that the generator reserve with the hybrid system by cooperation between the hydrogen energy and gasoline can be saving 7.20 baht/hour of the electricity cost. If using the generator for 6 hours a day, it will be able to pay back the investment cost within 7 months. The environmental aspect, it also releases less carbon monoxide, carbon dioxide and pollution compare the generator with only one fuel.

Keywords: Generator reserve1, Hybrid system2, Hydrogen energy3.

1. Introduction
At present, Thailand has used gasoline in the transportation and communications industry. The energy used is oil, which has a high cost and affects the environment. The trend of oil use has increased. Carbon dioxide emissions are higher than 4 million tons per year [3]. The carbon emissions also cause global warming. Therefore, the energy consumers in Thailand have tried to find alternative energy. The reductions of oil consumption are minimizing pollution. The concept of using other fuels is to replace oil consumption. Hydrogen is the chosen energy to study. It is a clean and pollution-free fuel by separate water with electricity to obtain hydrogen and oxygen. Hydrogen production from the electrolysis process is a simple and inexpensive technology [9]. Hydrogen can be produced as a fuel for future human energy needs. It can also be used as fuel with gasoline and diesel in internal combustion engines [5], [7]. The use of hydrogen fuel for internal combustion engines still requires development and research. The research was producing a more efficient and more efficient production. This research aims to develop the use of hydrogen fuel from the separation water with electricity to use as fuel for the power generator of the reserve generator.

Therefore, this study is to develop a hybrid reserve generator system by cooperation between
the hydrogen energy and gasoline. It can reduce fuel consumption and reduce energy costs.

Research objective
- To develop a hybrid reserve generator system by cooperation between the hydrogen energy and fuel energy.
- To test the efficiency of the hybrid reserve generator.
- To analyze the economics of the hybrid reserve generator.

Research Scope
The development of a hybrid reserve generator system by cooperation between the hydrogen energy and fuel energy power is 5 KW 220 V. The electricity test load is a 1000 W bulb.

2. Materials and methods
2.1 Study the problems and efficiency of the current reserve generator.
2.2 Design a hybrid reserve generator backup system by cooperation between the hydrogen energy and gasoline with the equipment and tools used in research include Hydrogen Separator [1]. The hydrogen separator powers the engine power generator. The Hydrogen separation is powered by 12 V 45 A batteries. There is a flow meter that can adjust the flow of hydrogen to the engine. The generator has limited the power as 5 KW 220 V, the speed control at 1500 rpm for use in load testing by a 1000 W bulb. The exhaust emissions are measured by the combustion of hydrogen-powered engines (Fig. 1).

Fig. 1: Equipment and Tools

The equations of the technical Analysis of Hydrogen Production from the separation of electricity are analyzed include:

Volume of hydrogen gas

$$V_{H_2}$$ and the oxygen gas $$V_{O_2}$$ calculate from Faraday's first rule as shown in equation 1 [2].

$$V_{H_2(Theory)}(m^3) = \frac{R \left(\frac{1}{mol}\right) I \left(A\right) T\left(K\right) t\left(s\right)}{F\left(\frac{1}{mol}\right) P\left(Pa\right) Z\left(\right)}$$

(1)

When

$$V_{H_2(Theory)}$$ is hydrogen volume ($m^3$)

$$R$$ is constant gas value (8,314 J/mol K)

$$\rho_{H_2}$$ is the density of hydrogen produced (0.0899 kg/m$^3$)

$$I$$ is the electricity supplied to the electrolyser (A)

$$T$$ is ambient temperature (K)

$$t$$ is time (S)

$$F$$ is the Faraday's constant (96485C/mol)

$$P$$ is atmospheric pressure ($1.013 \times 10^5 Pa$)

$$Z$$ is the number of electrons ($H_2 = 2, O_2 = 4$)

Note: In case of oxygen volume ($V_{O_2}$) change Z to 4 instead of Equation 1.

Faraday efficiency

Faraday efficiency calculation can be obtained from the ratio between volume of gas produced and the volume of the product produced by the theory is shown in Equation 2 [4].

$$\eta_{faraday} = \frac{V_{H_2}(m^3)}{V_{H_2(Theory)}(m^3)}$$

(2)

When

$$\eta_{faraday}$$ is the Faraday efficiency

$$V_{H_2}$$ is the volume of hydrogen produced by the test ($m^3$)

Electrolyser efficiency

The efficiency of the electrolyser means that energy efficiency of hydrogen heating compared with the use of electrical energy in gas production as equation 3 [4].

$$\eta_{Ther}(\%) = \frac{V_{H_2}\left(\frac{m^3}{s}\right) H_{HV}\left(\frac{kI}{m^2}\right)}{I\left(A\right) V\left(V\right)} \times 100$$

(3)

When
\( H_{\text{HHV}} \) is the hydrogen charge in the form of heat (12.75 MJ/m³)

\( V \) is the voltage supplied to the electrolyser (\( V \))

2.3 Create a hybrid reserve generator system by cooperation between the hydrogen energy and gasoline include HHO system (Fig. 2) and Hybrid reserve generator. (Fig. 3).

A) Pulse modulator       B) Battery       C) HHO generator
D) Bubblers       E) Water tank       F) Voltmeter

Fig. 2 : HHO system

Fig. 3 : Hybrid Power Generator

2.4 Test the operation of the hybrid reserve generator system by cooperation between the hydrogen energy and gasoline such as hydrogen production, electricity usage for Hydrogen Separators and temperature of Hydrogen Separator.

2.5 Evaluate the efficiency of the hybrid reserve generator system by cooperation between the hydrogen energy and gasoline include Hydrogen-powered hydrogen generator test with no load and load, determine the amount of fuel used and measure the amount of pollutant generated by the combustion of the engine by calculating the percentage of CO.

2.6 Analyses the investment cost of developing the hybrid reserve generator.

3. Results and Discussion

The resulting analysis was divided into 6 parts.

3.1 The amount of hydrogen produced per period.

The results showed the amount of hydrogen produced per period. The maximum amount of hydrogen is 0.46 litres per minute (Fig. 4).

Fig. 4 : Hydrogen productions.

3.2 Electricity with hydrogen separators.

The results showed that the electricity used for the hydrogen separator was 12.4 A after the 5-hour test. As the temperature rises, the water vaporizes, resulting in a higher concentration of the solution (Fig. 5).

Fig. 5 : the amount of electricity

3.3 Water Temperature in the hydrogen separator.

The results of water temperature test in the hydrogen separator showed that the water temperature will increase continuously as the water
volume decreased. The higher water temperature is due to the increased electricity current (Fig. 6).

Fig. 6 : Water Temperatures in Hydrogen Separator

3.4 The generator test

The experimental results of the trial run without load showed that the use of gasoline was 1 liter, the generator was able to operate at an average of 48.01 minutes. The use of 1 liter of gasoline combined with hydrogen, the generator can work an average of 55.73 minutes. The generator test result showed in table 1.

Table 1 : the generator test with off load

<table>
<thead>
<tr>
<th>Off load (minutes)</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>X</th>
</tr>
</thead>
<tbody>
<tr>
<td>gasoline (1 litre)</td>
<td>48.15</td>
<td>47.52</td>
<td>48.36</td>
<td>48.01</td>
</tr>
<tr>
<td>gasoline (1 litre)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>+ hydrogen</td>
<td>55.16</td>
<td>56.79</td>
<td>55.24</td>
<td>55.73</td>
</tr>
</tbody>
</table>

The experimental results of the trial run with load showed that the use of gasoline was 1 liter, the generator was able to operate at an average of 43.94 minutes. The use of 1 liter of gasoline combined with hydrogen, the generator can work an average of 47.74 minutes. The generator test result showed in table 2.

Table 2 : the generator test with on load 1000 W

<table>
<thead>
<tr>
<th>On load 1000 W (minutes)</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>X</th>
</tr>
</thead>
<tbody>
<tr>
<td>gasoline (1 litre)</td>
<td>43.62</td>
<td>44.53</td>
<td>43.68</td>
<td>43.94</td>
</tr>
<tr>
<td>gasoline (1 litre)</td>
<td>47.71</td>
<td>47.56</td>
<td>47.95</td>
<td>47.74</td>
</tr>
<tr>
<td>+ hydrogen</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

3.5 Pollution from combustion of engine

The impact on the environment is measured by the various pollutants generated by the combustion of the engine. It can be seen that when using hydrogen as cooperate fuel, the carbon monoxide, Carbon dioxide and other pollutant value is lower compared to the single gasoline (Table 3).

Table 3 : Pollution results

<table>
<thead>
<tr>
<th>fuel</th>
<th>load</th>
<th>CO (%) vol</th>
<th>CO₂ (%) vol</th>
<th>O₂ (%) vol</th>
</tr>
</thead>
<tbody>
<tr>
<td>gasoline</td>
<td>Off</td>
<td>0.42</td>
<td>10.48</td>
<td>2.75</td>
</tr>
<tr>
<td>gasoline + hydrogen</td>
<td>Off</td>
<td>0.23</td>
<td>9.91</td>
<td>4.52</td>
</tr>
<tr>
<td>gasoline</td>
<td>On</td>
<td>0.57</td>
<td>12.64</td>
<td>1.95</td>
</tr>
<tr>
<td>gasoline + hydrogen</td>
<td>On</td>
<td>0.35</td>
<td>11.62</td>
<td>2.47</td>
</tr>
</tbody>
</table>

The carbon content is 0.42% by volume in the gasoline engine test. The load test causes the carbon content to be 0.57% by volume. The carbon content of the gasoline with hydrogen engine without load test was 0.23% by volume and the gasoline with hydrogen engine load test was 0.35% by volume (Fig. 7).

Fig. 7 : CO% values generated by the engine.

The carbon dioxide content is 10.48% by volume in the gasoline engine test. The load test causes the carbon dioxide content to be 12.64% by volume. The carbon dioxide content of the gasoline with hydrogen engine with load was 9.91% by volume and the without load test was 11.62% by volume (Fig. 8).
3.6 Economic Evaluation

On-load 1000 W with 1 liter of hydrogen, the engine run 47.74 minutes, gasoline 95, cost 37.66 baht per liter, cost 0.78 baht per minute. It saves 0.12 baht per minute, engine running 6 hours a day. This is a saving of 15,552 baht per year with a payback period of 7 months.

4. Conclusion

The development of the generator reserve with the hybrid system by cooperation between the hydrogen energy and gasoline power 5 KW 220 V at 1500 rpm. Based on the results, the maximum hydrogen production per period is 0.46 liters per minute. The electricity used for the hydrogen separator is 12.4 A, when comparing the generator run time with 1 liter of fuel. It is found that the use of generators with single fuel can work an average of 48.01 minutes. However, the generator can operate at an average of 55.57 minutes using hydrogen energy with gasoline. The test runs on a generator with a 1000 W load. The generators can operate at an average of 43.94 minutes, but when using hydrogen power combined with gasoline generators can work an average of 47.74 minutes. Environmental impact carbon monoxide, carbon dioxide and other pollution value are lower compared to the fuel. In accordance with the research [1], [6] the use of co-fuels reduced global warming potential by 5.38 kg-CO$_2$equivalent Compared with oil use. The potential for global warming as fuel consumption is 22,425 kg-CO$_2$equivalent. Economic analysis, it was found that after the renovation by installing hydrogen separators into the system, the electricity saving cost is the previous 7.20 baht/hour. The cost of installing the equipment is 10,000 baht. If the generator is 6 hours per day, 365 days per year, the electricity cost is about 3.50 baht per unit. The payback period is 7 months. In accordance, with the research [8] with the use of hydrogen as a co-fuel with an average saving was 17%. The advantage of using hydrogen from the electrolysis process is that it can be produced at any time. In addition, it depends on the characteristics of the engine and other components in the test.

5. Acknowledgements

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6. References


