Experimental research on asynchronous wave energy power generation system

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ABSTRACT: In order to make better use of wave energy, based on floating wave energy device, a new asynchronous wave energy generation system is presented in this paper. Being different with traditional floating wave power generation system in which the motion of hydraulic cylinder piston rod on both sides of the system is synchro-nous operation, the new system is designed for the bilateral asymmetric cylinder stroke operation conditions, expecting the new system can be used in more complex occasions. In this article, the power captured in three different conditions is analyzed through the experimental method, in which the average motion cycle of 4 seconds is selected to investigate the influence of wave period on the power. The performance of the asynchronous condition is very well under the same period. Comparing with the performance in synchronization conditions, the performance of asynchronous system is not too bad, and the power has a higher peak.
KEYWORD: Asynchronous condition; power analysis; wave energy; power generation system

1 INTRODUCTION

The earliest utilization of Wave energy can be traced back to 1799 years .When a French named Gillard and his son presented wave energy mechanical invention in1970s, many Marine countries developed wave development and research technology actively, they had made great progress. Britain, which studies the wave energy of great importance and commits itself to the use of pneumatic turbine Wells, the prototype wave generator, navigation buoy wave forces turbine generator set and small wave energy converters are also their research focus. Its wave power technology is at a leading level in the world. Because Japan is an island, with small territory and strained resources, research and development of wave energy are also quite active, wave energy conversion technology practical aspects is in the top of the world (Maehaute, et al. 1968; KOFOED P et al. 2006; Guo Xun. 2005). Norway is mainly contributed to the theory of design for the wave power device.

Sweden had tried the 30 kW hose pump field tests of the prototype device in the 1980s, and built one 1000 kW wave force demonstration plants outside the Atlantic coast of Spain. According to incomplete statistics, there are at least 28 countries (regions), which have studied the wave energy, have constructed thousands of wave power plants, have installed capacity with more than 800000 kW in total.The number of building and power are rising at an annual rate of 2.5% and 10% respectively(Zhao Xin. 2013; Zhang Lei. 2014; Henderson R. 2006; XU Xiao Mei. 2000). But most of the wave energy power generation devices are large-scale, and high power equipment, and the devices are costly to build and its construction is difficult. For the floating type wave energy power generation device, because of its structure, its application has some limitations (Palme, A. 1990; Wendel K. 1956; De, S. C. 1955) .In this paper .A new type of small power asynchronous wave energy power generation device has been designed, and the type of it belongs to the raft wave energy power generation device. By studying the power effect, it can effectively increase applications of the raft of wave energy power generation device.

2 EXPERIMENTAL CONDITIONS

2.1 *Hydraulic principle*

Figure1 shows the difference between floating type wave energy power generation device system and asynchronous wave energy power generation device system.

The operation principle of the system: Because the motion rules of hydraulic cylinder piston rod on both sides of the system is no longer synchronous operation, so the system operation condition is relatively complex. A brief explanation is given here: by the operating mode of floating type wave energy power generation system, assuming that the left of the system on a downward route, and the right of the system on a upward route at the same time, now the hydraulic oil in the system from two hydraulic cylinders through hydraulic tube into the hydraulic motor, let the motor rotate at the same time, the rotation of the hydraulic motor drives the generator to generate electricity, hydraulic oil back into the system of hydraulic cylinder through the one-way valve, when the right side of the left sideor is ascending or descending, the hydraulic oil from both sides of the systems flows into the hydraulic motor along the same path as the function of the hydraulically operated direction control valve .Due to the effect of one-way valve, the path of the hydraulic oil is fixed, and there will be no reversal of the hydraulic motor. This kind of condition is asynchronous condition, according to the working principle of the asynchronous wave energy power generation system. When the left of the system is resting, the right of the system is upward or downward, this is working condition of single cylinder movement, studying the actual generating effect of three conditions is also one of the important research contents in this paper.

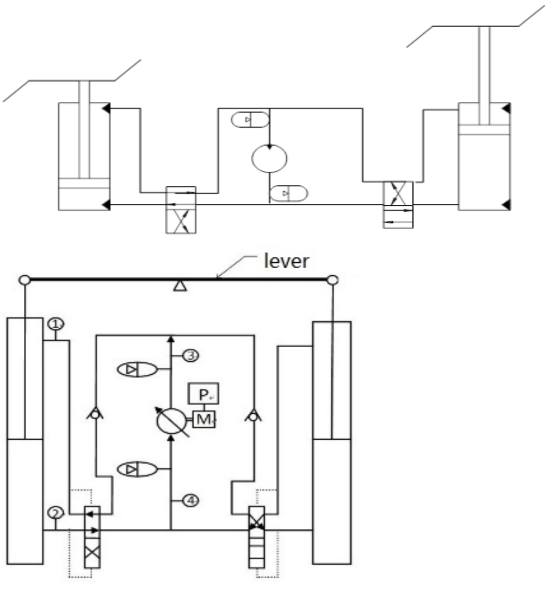

Figure 1 System comparison chart

2.2 *Data acquisition system*

In order to intuitively evaluate the output power of various conditions, a Yokogawa WT1800 power analyzer is adopted to measure all parameters of the output power and make evaluation. Physical object is shown in figure 2. The power meter has a strong ability to collect data, and it has six modules in total. Three modules are used in this article, i.e. the voltage, current and power, shown in figure 2.

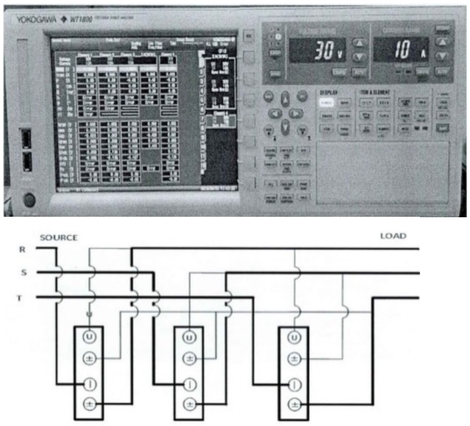

Figure2 Power Analyzer

Because the generator output is DC28V, the generator internal is three-phase three-wire, and the connective type is star, the output voltages with the SOURCE of the figure. Three resistances are used, corresponding to the LOAD in the picture, and the resistances are all 2.2Ω.

2.3 *The composition of the experimental system*

In order to satisfy the asynchronous wave energy power, the generating equipment and the various equipments are need to be designed as much small as possible. It can increase the difficulty of equipment type selection, and equipment is designed through analyzing the influential factors of each equipment.

Due to the need of a low power, selection is done of the permanent magnet generator whose rated power is 50W, with the specific model of FF-50W/500r/28v. The efficiency of the device is higher than 70%, according to the requirements of the rotation speed and torque of permanent magnet motor, the hydraulic motor with Bmm8 is chosen to combine with power generation. In the choice of hydraulic cylinder and hydraulic operated direction control valve, HOB Φ20x150 and 24 YF30-E10B are chosen respectively.

According to the requirements of power generation we select hydraulic cylinder of 20mm diameter and 150mm schedule, because cycle is 3.5s, we calculate that the flow I = 3.23 L/min.

The hydraulic motor of BMM-8 is chosen with the least displacement. The theory speed of hydraulic motor can be concluded: R=775/8 =400 R/min. According to the electrical generator testing curve can estimate (figure 3).

Figure 3 experimental apparatus

3 THE ANALYSIS OF EXPERIMENT RESULTS

3.1 *Influence of operating conditions*

In order to get the factors which can influence the power of wave power device better, different working conditions are adopted. The cycle as 8s, 6s, 4s, 3s are chosen respectively. The powers under three kinds of working conditions in real-time cases are analyzed and compared.

(1) As cycle is 8s, the experiments under three kinds working conditions are conducted, and the real-time voltage and power are shown in Figure 4.

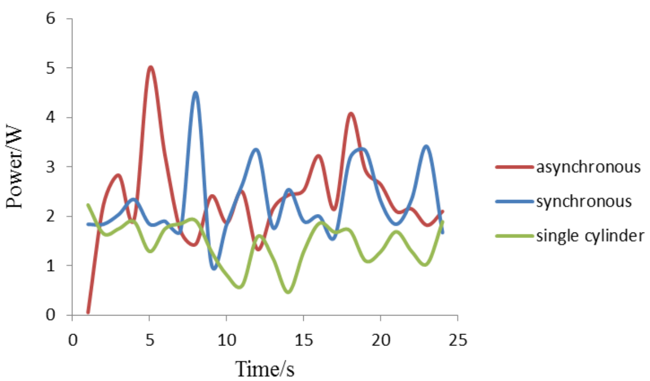

Figure 4 power curve

It is shown that when the wave period is 8s, the power of asynchronous conditions and synchronous conditions are far greater than the power of single cylinder conditions. If the wave period is constant, the voltages and powers can be influenced by three kinds of working conditions, and the power is fluctuant as a whole, this is because under the actual wave, the hydraulic lever of the hydraulic cylinder promotes the hydraulic oil flows through the valve, makes the valve feel the change of press, the valve core is acting at this time, because the partial pressure is too high, making the system a bit stalled in a cycle. There is a wave, a trough. This phenomenon may be explained according to a specific stroke in a cycle: When both hydraulic lever are downward at the same time, power will grow to peak from zero, at this time the valve reverses. Power can be reduced trough at a rather fast speed, and then the hydraulic lever begins up going, with power increasing to a peak gradually.

(2) As the cycle is 6s, the experiment is done in three kinds of working conditions, the real-time voltage and power are as shown in Figure 5.

As shown in the figure, the wave period is changed to 6 seconds. According to the chart, t still meets the above conclusion, and it can be seen that the electric power of asynchronous condition and synchronous condition are rising alternatively. This is because that under the synchronization state, the hydraulic cylinder is rising or falling alternatively, in a cycle, there will be half a period of time, the flow of synchronous conditions is greater than the asynchronous condition, in other half of the cycle, the flow of asynchronous condition is greater than the synchronization condition. And the Peak of asynchronous is greater than synchronous condition, because the asynchronous condition has the situation where both sides are head port with, maximum flow, making the speed of the generator the largest.

(3) As cycle is 4s, the real-time voltage and power are shown in Figure 6.

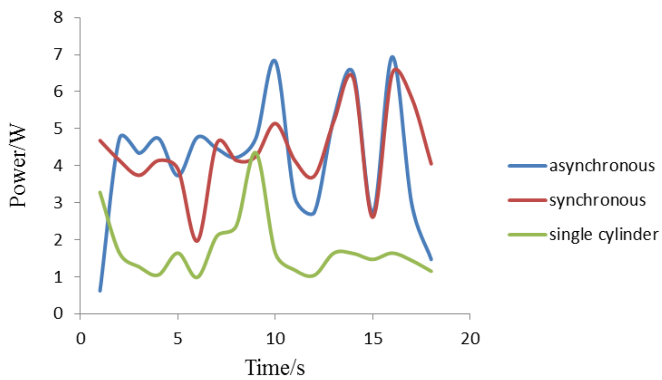

Figure5 power curve

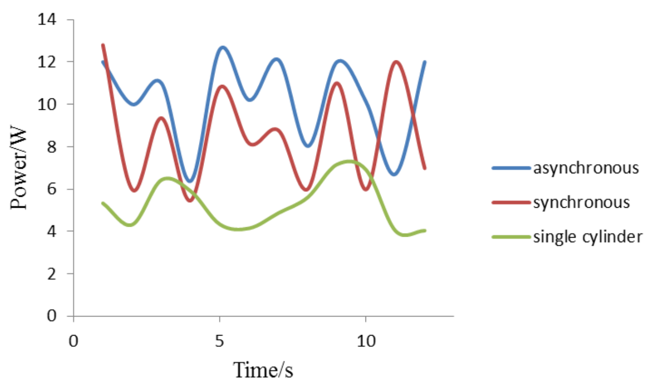

Figure 6 power curve

According to the image: when the wave period is 4s, voltage and power have an obvious drop after a period, this is because when the valve is reversing, the partial pressure is too high, it leads to voltage generated slump very quickly. The peak power of asynchronous condition can reaches 12.8W, the peak power of synchronous condition can reach 12W, the power peak of single raft body condition can achieve 7W. Because the experiment control variables are cycling, so in the same cycle, the time of rod port and head port is the same, in this case, the flow of head port is greater than that of the rod port, It makes a high peak power. From the results of the experiment, it meets the theoretical analysis, for the period of 4 seconds. It is close to the actual wave cycle, the voltage and power are more representative. We can see that the average of the electric power is close to 11W and 9W under condition of asynchronous and synchronous. The average power of single raft body condition can be close to 5W because the flow is relatively small.

（4）As the cycle is 3s, the real-time voltage and power are shown in figure 7.

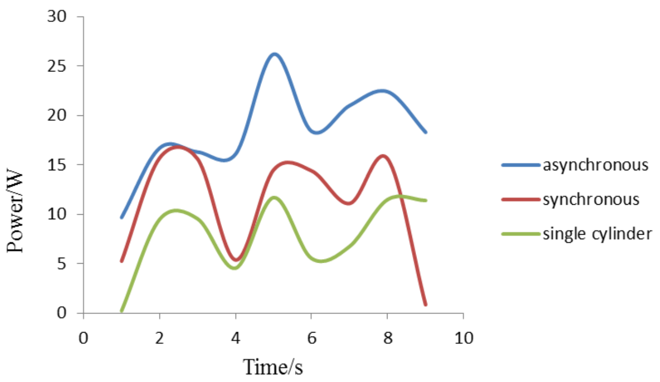

Figure 7 power curve

As shown in the figure: It meets all of rules concluded above. The power of three kinds of conditions can reach 10W. It can prove that power effect is good.

3.2 *Influence of cycle*

According to the figure 8: under the three kinds conditions, with the increase of wave period, the power gradually reduces, this is mainly because that small cycle leads to flow increasing. It can be found that the influence of asynchronous condition is bigger than others. It may be caused by the largest system pressure in this condition. With decreasing of cycle, the amplitude of increase of flow system will be bigger, and the curve will be steeper.

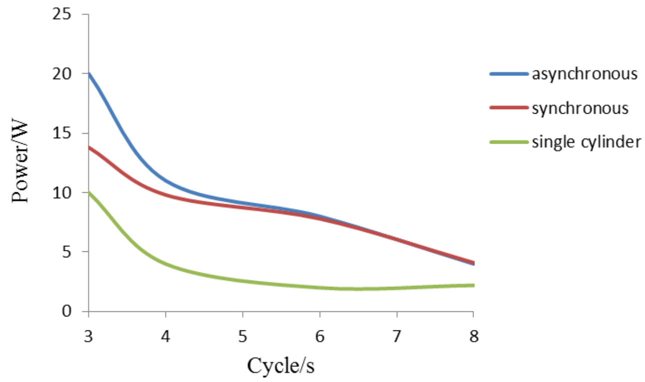

Figure 8 the Influence of cycle on power

3.3 *Analysis on the performance of the generator under continuous work and incomplete route*

In order to analyze the power of asynchronous condition under practical situation, the experiment is conducted under asynchronous (incomplete) state. This is because the comprehensive influence of wave force and wave height can make the hydraulic cylinder piston rod stroke be in incomplete route. In order to verify the effect on power, the following several experiment are completed.

(1) Continuous running under asynchronous condition

The results are shown in figure 9 and figure 10.

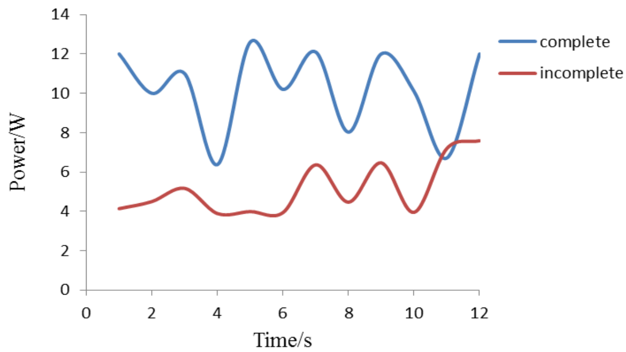

Figure 9 the influence of stroke on power

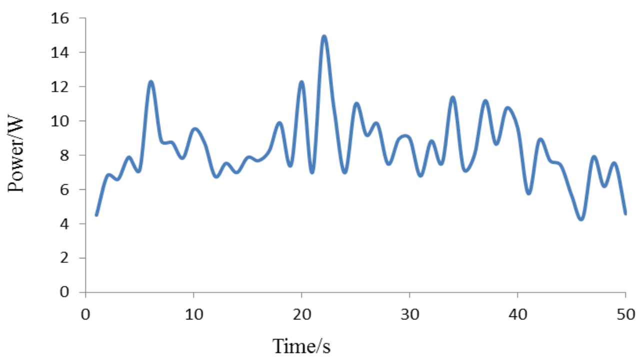

Figure10 Continuous asynchronous condition

From the experimental data: when the system working in a continuous state of asynchronous, the effect of the valve makes power fluctuation bigger in asynchronous condition, this is because when bilateral hydraulic cylinder upward or down ward, the oil will overcome larger resistance, making the ideal effect of the valve. According to the data results the power is smaller than that of asynchronous condition, but the effect of power fluctuation is small, more continuous and curve more flatter, which may be due to incompleteness, the system pressure is relatively small, the hydraulic damping is small, making the valve more sensitive, the effect of directional control is good, making electricity be continuous. Therefore, the power effect of asynchronous condition is related to the wave period and wave height.

(2) Continuous running under synchronous condition

The results are shown in figure 11 and figure 12. The rules of synchronization state is similar to the rules which are mentioned above.

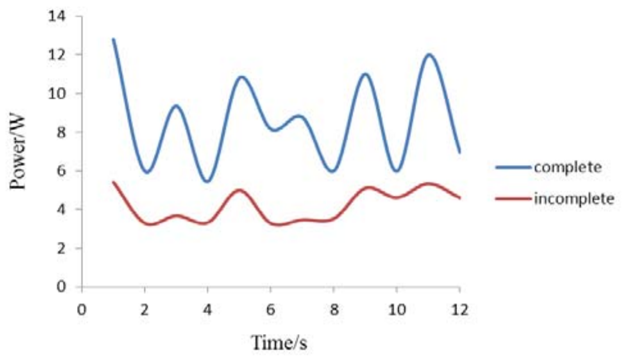

Figure 11 the influence of stroke on power

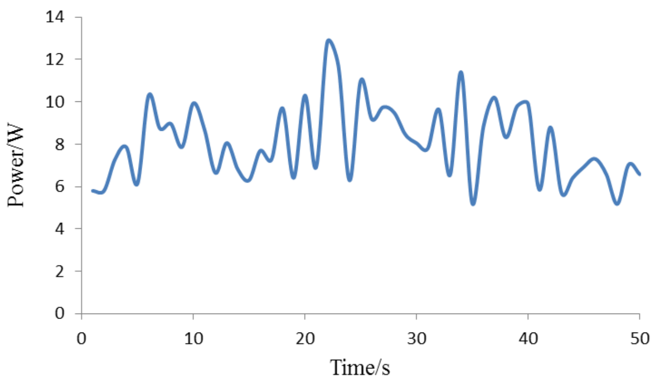

Figure12 Continuous synchronization conditions

4 CONCLUSION

This paper takes the asynchronous wave energy power generation as research object. Experimental method was adopted to analyze its power performance. The main conclusions are as follows:

(1)The working conditions of asynchronous and synchronous almost have no difference, but power of single cylinder condition is less than the first two.

(2)Properties are studied on different wave cycle of 3s, 4s, 6s, 8s. On the premise of full stroke, if the cycle is smaller, the performance of wave power device is better.

(3)When the device is in continuous operation, it can meet the power needs of low power device, such as the buoys.

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