Proceedings of the
International Conference on Mechanical Engineering and Renewable Energy 2013
(ICMERE2013) 1 – 3 May 2014, Chittagong, Bangladesh

ICMERE2013-PI-292

CONTROLLING OF ELECTRICAL POWER PRODUCED FROM WAVE ENERGY

M. J. Islam[1, *], **M. S. Hossain**[2] **and M. A. Ullah**[3]

Department of EEE, Chittagong University of Engineering and Technology, Chittagong- 4349, Bangladesh.

[1,*] bipul_baf27@yahoo.com, [2]eee_bappi@yahoo.com, [3]ahsan@cuet.ac.bd

Abstract- *Due to increasing demand of power, it is time to think about producing more and more for fulfilling the requirement properly. Fossil fuels are predicted to be finished in near future, so renewable energy is the only reliable source to produce demanding power. Wave energy has bountiful potential in this aspect because of cornucopia of water and wind resources throughout the world. Generating modules used for power generation from wave produces small power which leads to use of array of modules to accrue appreciable amount of power. For obtaining maximum attainable power, efficient and accurate controlling methods are needed. Major controlling challenges are minimizing circulating current, detecting faulty generator, bypassing non-producing and faulty generators. This paper covers the overcoming of these challenges. Prediction is made that these works will be effective and conducive in producing power from wave in a large extent which will drag the hike of power crisis.*

Keywords: Wave energy, Control, Circulating current, Bypass faulty generator.

1. INTRODUCTION

Now-a-days electrical energy is must in our daily life. With the improvement of standard of life power consumption is increasing day by day. Only renewable energies can satiate the increasing demand as these are never going to run out. Major renewable sources are sun, wind, biomass, biogas, geothermal etc. But with the development of technology it is now possible to produce an appreciable amount of electrical energy from water resources. Water gives neat and clean electrical power which is environment friendly. It is very much effective to use water resource as a form of wave. Wave energy could be the major renewable energy source for some country like Bangladesh as they are blessed with huge sea resources. This paper is concerned with efficient use of electrical power produced from wave energy by introducing some controlling method. Those controlling methods are mainly focused on getting large amount of electrical power by using series-parallel combination of small production device and overcoming of some challenges which are introduced for using this combination.

In previous year several works have been done on power production from wave energy all over the world. But all works are focused on energy conversion using large sized generator but this paper working with producing large amount of power using small sized generator. Illustrious few previous works are given below.

Figure 1: Pelamis Wave Energy Converter [1].

1.1 The Pelamis Wave Energy Converter

It is a Scottish invention. It is consisted of six articulated cylindrical shapes of 3.5 m in diameter and 30 m in length [1]. This articulated structure with 140 m in a total length is placed 2/3 semi-submerged offshore in deep waters, which is shown in figure 1.

Due to the waves, this structure up and down and side to

side as a sea snake (Pelamis in Greek).

Each of these four modules shown in figure 1 has a 250 kW electric generator individually giving a total power of 750 kW for each Pelamis unit. A 10 kV three phase power transformer is situated in the front floater and send the electric energy across underwater power cables to a substation in land.

Figure 2: Pelamis wave farm [1].

Figure 2 shows an association of various numbers of pelamis units constituting a wave farm for generating large power.

1.2 Blue Wave Powered Generator

It is a very basic, massive and powerful engine submerged in the ocean and driven by multiple wave powered buoys (similar to the pistons of an internal combustion engine) [2]. This engine in turn drives a generator capable of providing the grid with free clean green electricity.

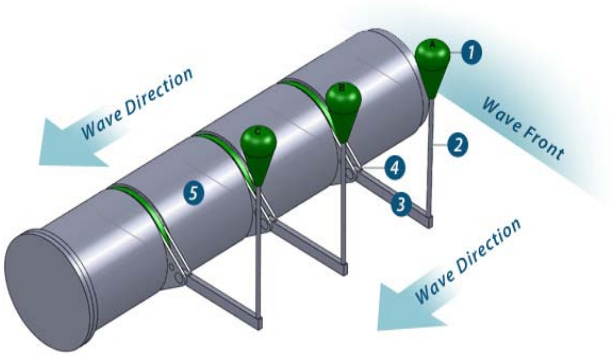

Figure 3: Blue wave power generator [2].

This paper will aid to fulfill the following objectives and utilizing the following scopes.

1.3 Objectives

(a) To use available water resources.

(b) To reduce the energy crisis by contributing in power generation from renewable energy.

(c) Using produced power more efficiently & cheaply.

(d) Increasing the efficiency by perfect controlling methods.

(e) Reducing the dependency on the fossil fuel.

(f) To ensure the permanent solution of power crisis.

1.4 Scopes

(a) Clean electrical power production.

(b) Supplying Power to the local island like Saint Martin, Bangladesh.

(c) Water desalination.

(d) Deformation of water and collecting Hydrogen (H_2) gas.

This paper will cover the following things with the sequence as follows. Section 2 gives the methodology of generating electrical power from wave energy. Section 3 covers controlling scheme. Section 4 gives the idea about challenges of the controlling arena. Section 5 covers the methods of overcoming challenges. Section 6 gives the idea about future work of this paper and Section 7 concludes the paper.

2. Methodology

Controlling methods would be same for any kind of generating modules which produces small amount of power individually. A method of producing power is considered here for convenience. Our concerned generator is a similar one as Blue wave power generator shown in figure 3.

2.1 Operating Description of the generator

From figure 3 waves picks up buoy A (1) which through cable (2) lifts its arm (3). This engages a one way clutch (4) resulting in shaft (5) being rotated a portion of a revolution. As the wave moves by, the buoy A goes down and cable becomes less tight, resulting in the downward motion of the arm due to gravity. This releases the one way clutch and the process is ready to be repeated.

While buoy A moves down, the wave has moved on and the whole process is repeated with buoy B and then C. In the meantime the next wave has moved in and the process is repeated from A to B to C and the following buoys (the machine may have hundreds of buoys). Using this mechanism a large amount of power is accrued from this method which is neat and clean.

This engine is coupled to a gearbox to speed up the rotation to the required rpm; the gearbox drives a generator to produce electricity. Though the concept of harnessing wave motion with the capacity of generating a perpetual power source without fuel is not new, this system has refined the concept to use it in its most basic form, making it far more economical in all key point areas, i.e. carbon footprint, cost, maintenance, visual impact etc.

3. CONTROLLING SCHEME

Power generation from uniform wave across each meter of wave front maintains the following equation [1]

$$P = \tfrac{1}{2} \rho g \gamma H^2 \qquad (1)$$

P=Expected power form wave energy in W/m
ρ =Specific weight of the sea water.
γ= Wavelength of wave found from Sea.
H= Height in meter.
g= Gravity acceleration.

It is known that, the specific weight of the sea water, ρ = 1.027; gravitational acceleration, g=9.8 m/s^{2,} if height of the wave is H= 0.3m, and wavelength of wave found in Sea is γ = 0.5m; then the output power that we expected is (1)

$$P = 0.5 \times 1.027 \times 0.5 \times 9.8 \times (0.3)^2$$
$$= 0.23 \text{ watt/meter}$$

As the generator produces very small power, so a large numbers of generators are needed to connect in series and parallel to produce appreciable amount of power. Theoretically combination circuit is given in figure 4:

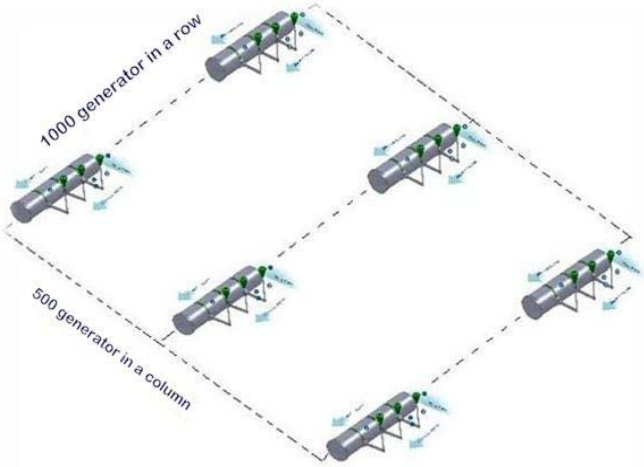

Figure 4: Series-parallel combination circuit.

In this figure shown that 1000 genearator connected in a row means in series. Again 500 generator is connected in a column means that 500 series line connected in parallel.

Here,
One generator is giving power about 0.23 Watt/meter.
Total no. of generator = 1000(series) x 500(parallel).

Total produced power,

$$P = (0.23 \times 1000 \times 500) \text{ Watt/meter}$$
$$= 115 \text{ kilo Watt/meter}$$

Doing series and parallel connection of generator produces some problems. Reducing of these problems is the main challenge and that is where controlling methods are needed.

4. Challenges of the controlling arena

(1) Reducing circulating current which produces when generator are connected in parallel.

(2) Detecting the faulty line when it is out of production.

(3) Bypassing the faulty generator to keep the continuation of power supply.

5. Methods of overcoming challenges

5.1 Reduction of circulating current

If we can maintain almost equal voltage in each parallel line, then there will be no circulating current. For maintaining equal voltage in parallel line we will use voltage regulator and Buck-Boost method.
Proteus simulation by using voltage regulator is given in figure 5.

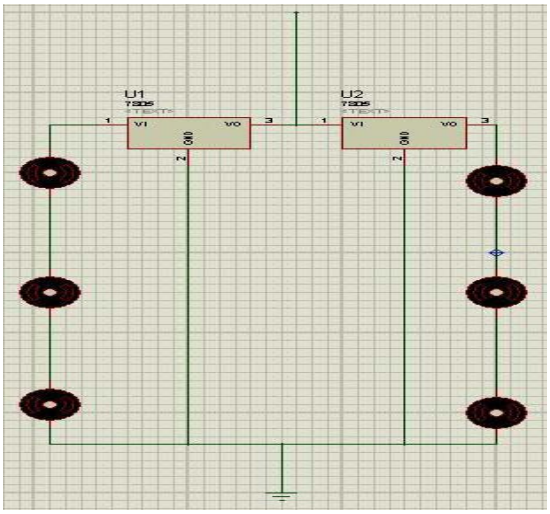

Figure 5: Proteus simulation for reducing circulating current.

Matlab simulation by using Buck-Boost method is given in figure 6:

```
File  Edit  Text  Go  Cell  Tools  Debug  Desktop  Window  Help
 1 -    n=4
 2 -    line1=rand(1,n)
 3 -    if line1(1)<1
 4 -        Unit1_sum=sum(4*line1)
 5 -    else
 6 -        Unit1_sum=sum(line1)
 7 -    end
 8 -    Line2=rand(1,n)
 9 -    if Line2(1)<1
10 -        Unit2_sum=sum(4*Line2)
11 -    else
12 -        Unit2_sum=sum(Line2)
13 -    end
14 -    Vref=6;
15 -    if Unit1_sum<Vref
16 -       [Unit1_voltage K1]=booster(Unit1_sum)
17 -    else
18 -         [Unit1_voltage K1] =buck(Unit1_sum)
19 -    end
20 -    R=10;r=2;
21 -    Unit1_current=Unit1_sum/(R+n*r)
22 -    Unit1_Power =Unit1_current* Unit1_voltage
23 -    if Unit2_sum <Vref
24 -        [Unit2_voltage K2] =booster(Unit2_sum)
25 -    else
26 -        [Unit2_voltage K2] =buck(Unit2_sum)
27 -    end
28 -    Unit2_current=Unit2_sum/(R+n*r)
29 -    Unit2_Power = Unit2_current* Unit2_voltage
30 -    Total_Power= Unit1_Power+Unit2_Power
31 -     fprintf('\n\n');
32 -    if abs(Unit1_voltage-Unit2_voltage)<.001
33 -        disp('There is no circulating current')
34 -    end
```

Figure 6: Matlab simulation for reducing circulating current by using Buck-Boost method.

Output of the simulation is given in figure 7:

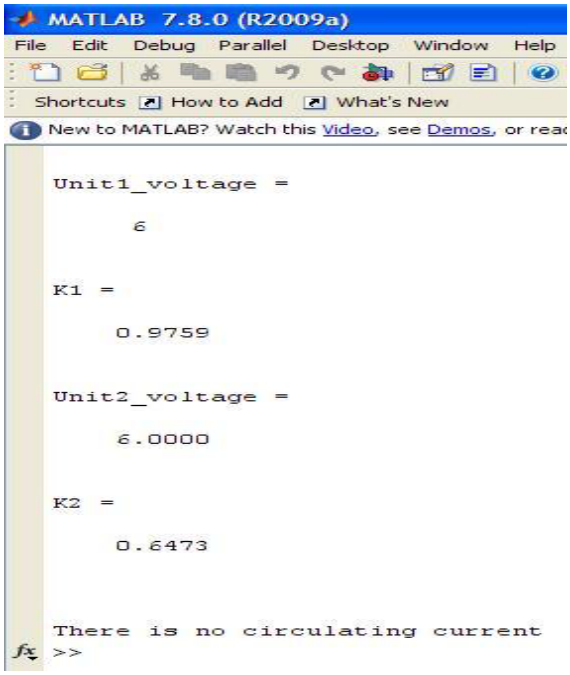

Figure 7: Output of the simulation.

5.2 Detection of faulty line

A digital ammeter is needed to be connected with each line and have to be monitored .When one of those lines will not be able to produce power ,then the ammeter reading will be zero which is the indication to a faulty line. Then this reading will be transferred to the control room by using GSM technology. Then control room will assist to take immediate action for the recovery.

5.3 Bypassing of faulty generator when it is out of production

A control circuit may use for this purpose. The control circuit may consist of transistor, comparator such as operational amplifier and micro controller. Transistor are using for switching operation, op-amp used for giving input to micro controller and micro controller is used for logic operation. Circuit description is given below:

A transistor is needed to be placed across each generator where transistor collector pin is connected in positive terminal of the generator, emitter pin is connected to the negative terminal and transistor base is connected with micro controller pin. The generator output is given to a microcontroller by op-amp. When a generator is out of service then its output will be zero which will make zero output of the op-amp. As a result input of corresponding pin of microcontroller which are connected with op-amp will be zero. After this a logic operation will held in microcontroller for the activation a pin of another port. This pin is connected with the base of transistor those are connected across the faulty generator. When transistor base is getting voltage from the active pin the transistor will be on and it will be short for transistor switching operation, making a close path across the faulty generator. This means that the generator is bypassed from the line and continuation of power supply is maintained.

Proteus simulation of bypassing circuit is given in figure 8:

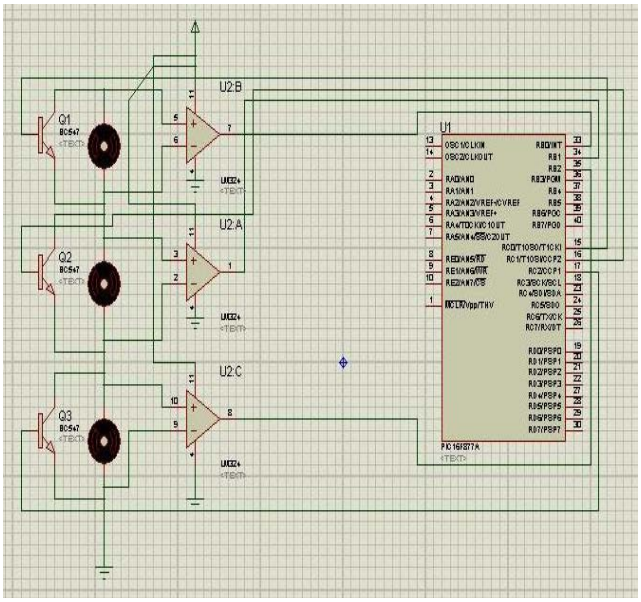

Figure 8: Proteus simulations for by-passing the faulty generator.

6. FUTURE WORK

Wave energy has a prolific future in the field of clean power production. This paper covered the controlling for dc power. Using this dc power a dc power system can be established for the sea coastal areas like saint-martin, Bangladesh. In future this works could be extended for grid integration using inverter. As most of the grid system throughout the world is ac, it could be a milestone to produce ac power using wave energy.

7. CONCLUSION

Power crisis is increasing day by day specially in developing country like Bangladesh. For developing countries it is a dire need to overcome the problem of power crisis soon. Renewable energy can be a great source to solve the power crisis. Wave energy has lots of potential in this aspect. This paper is trying to give a idea for producing large amount of electrical power by the wave energy by using combinational array of small generator and overcomes the problems which will be the constrain for this process. Wave energy converter is inexpensive to operate and easy to main. It produces no waste and gives clean energy. So lots of emphasis should be given on producing electrical power from wave energy and efficient controlling of it.

8. REFERENCES

[1]. L. Rodrigues, Dept. of Electrical and Electronic Engineering, Faculty of Science and Technology, Nova University of Lisbon, “Wave power conversion systems for electrical energy production.pdf”.

[2]. http://mahalapower.co.za (Date of access: 6 September, 2013).

[3]. www.icrepq.com/icrepq-08/380-leao.pdf (Date of access: 26 September, 2013).

[4]. M.S. J. Asghar, *Power Electronics*, PHI learning private limited, New Delhi-110001, 2009.