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HYBRIDIZATION OF HYDROPOWER, WIND ENERGY, SOLAR PV CELL IN CHITTAGONG, BANGLADESH

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Abstract- *Power is one of the most important factors for the development of any country. Conventional fossil fuels will be finished within half century, so renewable energy is the only solution to meet up the future crisis. It can be efficiently harnessed by using Hybrid Renewable Energy System (HRES). Our aim is to generate hybrid power from renewable energy sources by hybridization of hydro power, wind energy and solar PV cell. To avoid intermittency of electricity production in hydro plant during winter, pumped storage method can be deployed. In this method, power will be extracted by wind turbines. Further installation of wind turbine in the Chittagong Hill Tracts (CHT) & a large number solar PV cell can be set up in that region, so that power generated combining them can meet the peak load. Since, these renewable energies are relatively less costly & does not emit greenhouse gases, so this HRES is environmentally friendly. The Karnafuly hydro power station having a capacity of 230MW by 5 units. BPDB trying to increase its production up to 330MW. If we use HRES, it will be possible to fulfill the target and even more power can be generated. So, HRES will accelerate the power generation as well as establishment & expansion of industries in Bangladesh.*

Keywords: Renewable energy, Hybridization, Hydropower, Wind energy and Solar PV cell.

1. INTRODUCTION

Low-income developing countries like Bangladesh are very much susceptible to the setbacks arising from the ongoing energy crisis. Natural gas lies at the heart of the country's energy usage, accounting for around 72% of the total commercial energy consumption and 81.72% of the total electricity generated [1,2]. But this source of energy is diminishing in an alarming rate and cannot keep pace with the energy demand. If Bangladesh's GDP growth remains as low as 5.5 percent till 2025, the country will need to add 19,000 MW of additional power, causing the gas demand to spiral up to 4,567 million cubic feet per day by 2019-20 [3]. Such an overwhelming dependence on bio fuel has brought into focus the substantial amount of renewable energy resources available in the country. The potential non-exhaustive sources of energies, available in the form solar, biomass, biogas, hydropower and wind, can be harnessed to provide an environmentally sustainable energy security, as well as affordable power supply to the off-grid rural areas of the country. The government in its budget statement in June of this year has said that the Renewable Energy Policy has already been prepared and by 2015, it has, such as air, waste and solar energy.

A hybrid renewable energy system (HRES) is most effective and it is an emerging power generation technique. Massive implementation of renewable energy sources is a key element to reduce greenhouse gas (GHG) emissions associated to electricity generation. In this modern era, renewable energy development, optimum condition for the power production and utilization of energy system are considered to be an indubitable feature for the socio-economic development. Therefore, we present in this paper a contemporary overall scenario of hydropower, wind energy and solar energy for HRES implementation in Bangladesh particularly in Chittagong. For instance here hydropower of kaptai, solar and wind energy sources of Bangladesh and feasibility of implementation of HRES in decentralized and rural areas are studied.

2. LITERATURE REVIEW

Diverse region of the world especially economically developing countries seeks economically affordable and energies which emit less CO_2 and their citizens easily accept these energy. Over 1.6 billion people in the world lack access to electricity and approximately 80% reside in rural Asia and Africa. Also, because of the rise in the level of energy consumption across the global, researchers and energy experts have found the need to provide alternative methods of energy production. HRES is still an ongoing research hot spot especially to renewable energy (RE) experts and electrical power engineers. In this line of study, it was stated that solar radiation and wind are comprehensively the most favoured RES for their availability and inexhaustibility

[4]. In hybrid system, an integrated PV system, wind energy system and a battery units sharing DC-bus and AC-bus arrangement supplying energy to a load in the absence of utility grid can be configured to supply electricity [5, 6]. Afgan and Carvalho conducted a study on sustainability consideration for hybrid energy system [7].

3. GEPGRAPHICAL LOCATION OF KARNAFULI HYDRO POWER PLANT

The only hydropower plant in the country is located at kaptai, about 50 km from the port city of chittagong. This plant was commissioned on 30 March 1962 as part of the 'Karnafuli Multipurpose Project', and is one of the biggest water resources development project of Bangladesh. The dam initially had two hydropower units with a total capacity of 80 MW. Presently, the dam has five units with a total capacity of 230 MW and it produces approximately 2.92% of the electricity consumed in Bangladesh. The water storage capacity of the Kaptai dam is 11000 km^2.

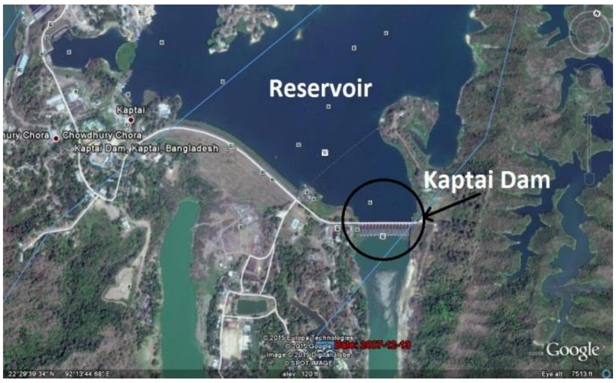

Fig.1: Satellite view of Karnafuli hydropower plant

Table 1: Basic features of the kaptai dam

Feature	Size/Type
Body of the dam	Earth
Length	670.6m
Height	45.7 m
Crest width	7.6 m
Maximum water level	33.5m (110 feet above mean sea level)
Minimum water level	20.1 m (66 feet MSL)
Capacity of 33m MSL	6477×10^6 m^3
Reservoir of 33m MSL	777 km^2
Spillway length	227 m
Maximum spillway discharge	16000 cumecs
Installed capacity (five units)	230 MW

Geographically, the CHT can be divided into a number of river valleys: Chengi, Maini, Kasalong, Rankhiang and Sangu . All these rivers except the Sangu are tributaries to the Karnafuli river, on which the Kaptai dam is located. These river valleys are 30–80 km long and 3–10 km wide, surrounded by hills a few hundred to a thousand meters high. In some places the valleys may be 20–30 km wide. These valleys are very suitable for agriculture and horticulture. The rest of the CHT mostly comprises hills and forests where the tribal people practice jhum (shifting slash and burn) cultivation. It includes 1538 km^2 of reserved forest and another 5400 km^2 of unclassified state forest areas.

4. SCENARIO OF HYDRO POWER, WIND ENERGY AND SOLAR ENERGY

Bangladesh is experiencing a gradual depletion of its primary energy resource i.e. natural gas and time has come to explore and harness the full potential of alternative energy sources to ensure our long term energy security as well as sustainable economic development. In this aspect, renewable energy can be a very effective one. Moreover, hybridization of renewable energy will be a more plus point to overcome scarcity of availability of energy. The status of different renewable energy are shown in following figure 2.

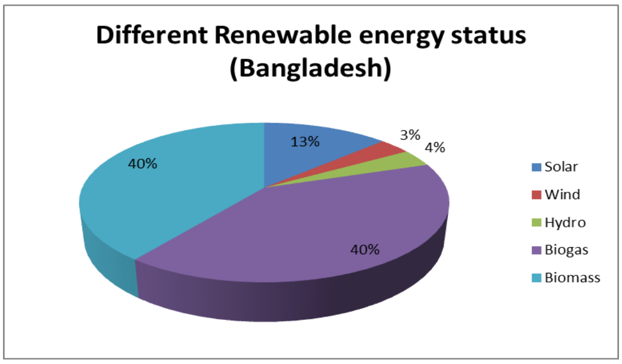

Fig.2: Different Renewable energy status in Bangladesh

4.1 Hydropower

Because of the geographic position, Bangladesh is a riverine country which is a huge advantage for the country. Bangladesh is a plain delta with having three of the world's major rivers the Ganges, the Brahmaputra and the Meghna flowing through it. The Jamuna-Padma Meghna river system divides it into east and west and creates an average water flow of 1.3 trillion m3 in a year throughout the country. Many other rivers flow throughout the country which are actually the tributaries of these rivers. Out of all the rivers about 57 rivers are transboundary originating from India and Myanmar [8]. During monsoon the flow rate of most of the rivers is high but it reduces substantially during winter. Hence the scope of hydropower generation is very limited in Bangladesh except in some hilly regions in the northeast and southeast parts of the country.

Micro hydro means generating up to 5-300 KW of electricity through hydroelectric power. It is a simple technology that converts hydropower to mechanical power. Micro hydro technology is very much suitable for a developing country like Bangladesh because it is a special source of energy which can generate energy without of fuel and the technology is very cheap. Because of the presence of many canals and tributaries of main river Karnafuli, Shangu, Matamuhuri which have very good potentials for setting up micro hydropower unit in Chittagong Hill Tracts region, recently

Sustainable Rural Energy (SRE) under LGED has successfully demonstrated first micro-hydro power unit at Bamerchara, Chittagong. Although the installed capacity of the unit was 10 kW but due to insufficient water head only 4kW power was generated.

Hydro power plants convert the Hydro power of the fluid into mechanical power which is further converted to electrical energy. Many types of hydro power plants can be setup according to the generation capacity i.e. Pico-Hydro (up to 5 kW), Micro-Hydro (5~300kW), Mini-Hydro (300kW~3 MW) and Small-Hydro (3MW~10MW).

The Karnafuli Hydro Power Station is the only hydropower plant in the country, having a capacity of 230 MW by 5 units. It is operated by BPDB (Bangladesh Power Development Board). BPDB is considering the increase of production up to 330MW. Two sites have been chosen for another two Hydro power plants at the Sangu and Matamuhuri rivers, one named The Sangu project (140MW) and the other The Matamuhuri Project (75MW). The Water Development Board (BWDB) and Power Development Board (BPDB) carried out a joint study on Micro-Hydro power potential in the country.

Table 2: Potential small hydro sites identified by BPDB & BWDB

Serial no.	District	Name River/Chara/ Strem	Potential of Electrical energy (KW)
1	Chittagong	Foy's lake	4
2	Chittagong	Chotokumira	15
3	Chittagong	Hingulichara	12
4	Chittagong Hill Track	Sealock	81
5	Chittagong	Lungichara	10
6	Chittagong	Budiachara	10

Sustainable Rural Energy (SRE) has explored some potential micro-hydro sites in Chittagong region which is listed in Table 3.

Table 3: Micro-Hydropower sites identified by SRE study

Site	Expected Power generation (KW)	Socio-economic infrastructure within 1 Km		
		House hold	School/ Mosque /Bazar/ Clinic	Small Indust-ry
Nanchari, Tholipara Khagrachari	3	100	3	1
Chang-o-par, Bandarban	30	200	5	2
Bangchari, Bandarban	25	600	12	5
Liragaon, Bandarban	20	500	8	3
Kamalchar, Rangamati	20	150	8	9
ThangKhrue, Rangamati	30	300	6	3
Monjaipara Bandarban	7.5	50	3	-

4.2 Wind energy

Bangladesh has 724 km long coastal line along the Bay of Bengal. The strong south/south-westerly wind coming from the Indian ocean enters into Asia over the coastal area of Bangladesh [9]. The wind blows over Bangladesh from March to September with a monthly average 3m/s to 6m/s. Wind speed in northeastern parts in Bangladesh is above 4.5 m/s while for the other parts of the country wind speed is around 3.5 m/s [10]. Wind energy can potentially generate more than 2000 MW of electricity in the coastal regions. The peak wind speed occurs during the months of June to July [11]. Park of wind turbines in coastal areas, can be incorporated in electricity grid on a substantial basis and could add reliability and consistency to the electricity generated by the Kaptai Hydro-electric power Station from March to September, during which load shedding becomes critical than winter season. So if a windmill is properly designed and located, it can supply considerable amount of energy. Recent study [12] has shown that out of various areas in Bangladesh, Kutubdia, Sandwip, and Kuakata have potential for wind power. Kutubdia and Sandwip both have high peak monthly average wind speed around April and May. This will result in high wind turbine performance. Its cumulative distribution also shows good result in which the profile shows low probability of wind speed below the cut-off speed. The wind speed characteristics of various places in Bangladesh are shown in the table 4 below.

Table 4: Feasibility of wind condition at different places of Bangladesh [13]

Site	Reference height(m)	Annual average wind speed(m/s)
Cox's Bazar	10	2.42
Sandip Island	5	2.16
Teknaf	5	2.16
Patenga Airport	5	2.45
Comilla Airport	6	2.21
Khepupara	10	2.36
Kutubdia Island	6	2.09
Bhola Island	7	2.44
Hatia Island	6	2.08

4.3 Solar energy

Bangladesh is a semi-tropical region lying in northeastern part of South Asia gets abundant sunlight year round. 70% of year sunlight is dropped in Bangladesh. It receives an average daily solar radiation of 4-6.5 kWh/m^2 and the annual solar radiation is as high as 1700kWh/m^2. Maximum amounts of radiation are available in the month of March-April and minimum in December-January [14]. The average bright sunshine duration in Bangladesh in the dry season is about 7.6

hours a day, and that in the monsoon season is about 4.7 hours. The highest sunlight hours received is in Khulna with readings ranging from 2.86 to 9.04 hours and in Barisal with readings ranging from 2.65 to 8.75 hours.

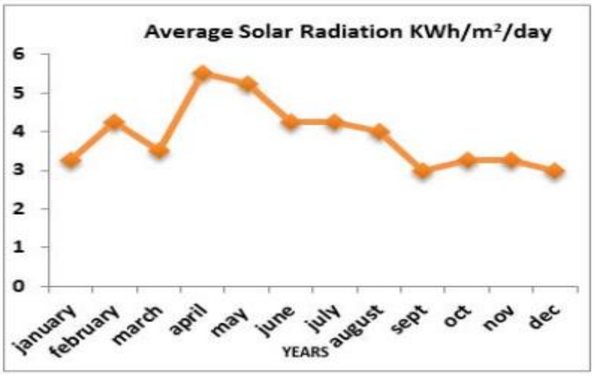

Fig.3: Monthly average solar radiation profile in Bangladesh [15]

The highest and the lowest intensity of direct radiation in $W/m^2$are also shown in the following figure:

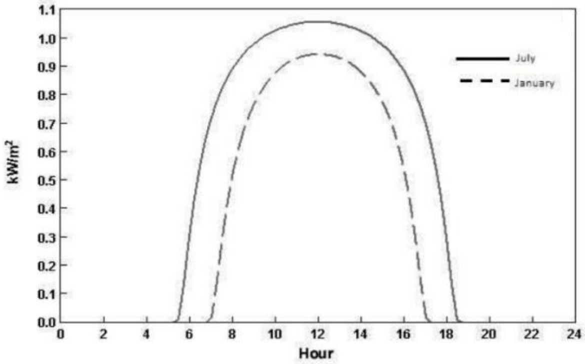

Fig.4: The highest and lowest intensity of direct radiation in W/m² [15]

5. METHODOLOGY

5.1 Hydropower

In a hydroelectric power plant, a power source is used to turn a propeller-like piece called a turbine, which then turns a metal shaft in an electric generator, which is the

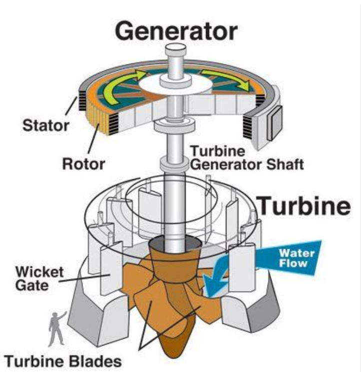

Fig.5: Electricity generation using water turbine

motor that produces electricity. The hydraulic turbine converts the energy of flowing water into mechanical energy. A hydroelectric generator converts this mechanical energy into electricity. In such type generator, there are electromagnets called field poles, and are mounted on the rotor perimeter. The rotor is attached to the turbine shaft, and rotates at a fixed speed. When the rotor turns, it causes the field poles (the electromagnets) to move past the conductors mounted in the stator. This, in turn, causes electricity to flow and a voltage to develop at the generator output terminals.

5.2 Wind energy

The wind energy conversion system (WECS) is composed of a permanent magnet synchronous generator (PMSG) driven by a wind turbine [16]. A shaft and gearbox connect the rotor to a generator, so when the rotor spins, so does the generator.

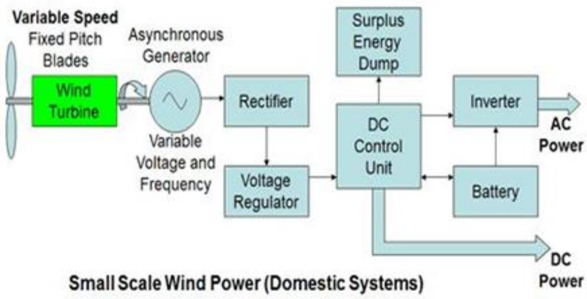

Fig.6: Electricity generation using wind turbine

The generator uses an electromagnetic field to convert this mechanical energy into electrical energy and controlled by a rectifier that connects the unit to the DC bus. The theoretical power P available in the wind impinging on a wind driven generator is given by:

$$P = ½CA\rho v^3 \qquad (1)$$

Where C is an efficiency factor (Power Coefficient), A is the area of the wind front intercepted by the rotor blades, ρ is the density of the air (averaging 1.225 Kg/m^3 at sea level) and v is the wind velocity.

5.3 Solar energy

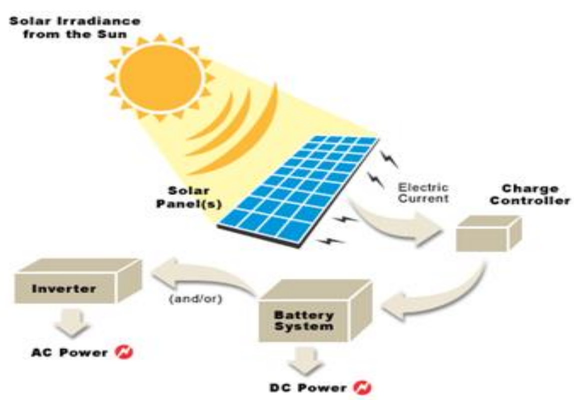

Fig. 7: Electricity generation using PV solar cell

In a PV cell, photons in sunlight hit the solar panel and are absorbed by semiconducting materials, such as silicon. Electrons are excited from their current molecular/atomic orbital. Once excited an electron can either dissipate the energy as heat and return to its orbital or travel through the cell until it reaches an electrode.

Current flows through the material to cancel the potential and this electricity is captured. An array of solar cells converts solar energy into a usable amount of direct current (DC). An inverter can convert the power to alternating current (AC). The most commonly known solar cell is configured as a large-area p-n junction made from silicon.

6. PROPOSED HYBRID RENEWABLE ENERGY SYSTEM

The main vision of the present system is to hybrid the above RESs for mitigating the power demand. With variable renewable power, the system must be able to provide a predefined constant power for housing applications, complementing the lack or excess of Wind/PV power sources using storage unit. These three elements are interconnected through a DC bus. The wind energy conversion system (WECS) is composed of a permanent magnet synchronous generator (PMSG) driven by a wind turbine and controlled by a rectifier that connects the unit to the DC bus. The solar module comprises several PV panels connected to the DC bus via a DC/DC converter which controls the operation point of the PV panels [16]. In order to maximize the economic value of the system, the PV source is intended to constantly operate at its maximum power [17].

Our proposed hybrid system is designed for both on grid and off grid operation to reduce dependency on the national grid for electrical supply. The figure 6 shows the block diagram of a typical hybrid grid connected power system. The system consists of PV generators, wind generator, micro hydro, battery bank, battery charge controller and the dump load. Here the input from solar and wind is directly connected to the Bus 2; whereas the input from hydro power generator are connected to Bus 1 which is fed by converting them from AC to DC. Here the dump load is used to put power when the batteries are fully charged. Then one the outputs from the Bus 2 fed to DC/DC converter for boosting which is served for various DC loads and another one is fed to charge controller which is used to control loads and inverter. So that we may get both DC and AC output.

The desired powers for DC loads are supplied from load controller to DC/DC converter to DC loads whereas an inverter is used to supply to the AC loads. There is a step up transformer which boosts up the output of inverter and this output goes to a controller. There is a charge controller which regulates the voltage and current coming from and going into battery. It also senses when the batteries are fully charged and to stop or decrease the amount of energy flowing from the energy source to the batteries [18]. A dump load is a secondary place to put power when the batteries are fully charged. Once the power has been diverted, it uses the power for something productive rather than lose it directly into the ground.

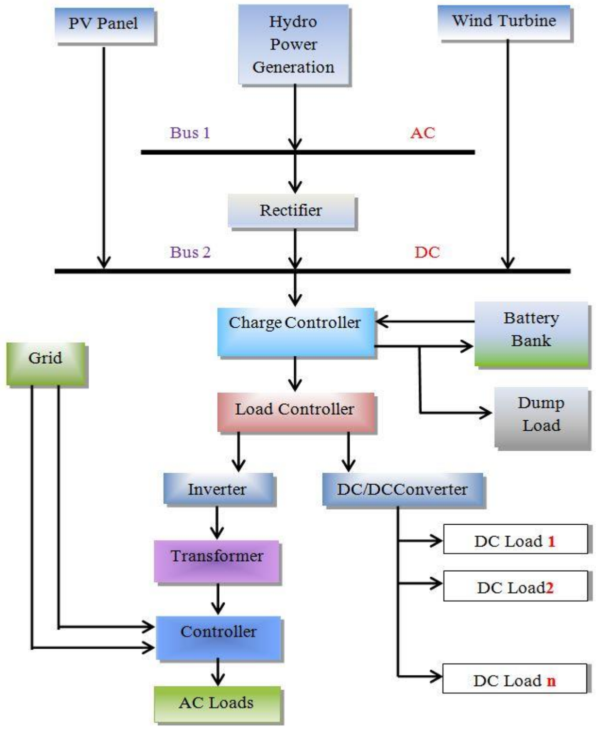

Fig. 8: Proposed Plan of hybrid Renewable System

Our proposed hybrid system will be very effective especially for remote areas of Bangladesh like Chittagong hill track, Cox-bazaar hill side and so on.

7. TOTAL POWER ESTIMATION

Solar power, P_{solar} = (Area per sq-ft × watts per sq-ft)
Wind power, P_{wind}= 0.5 ×ρ ×A ×v^3
Hydro power, P_{hydro} = H × Q × g × 1000
The total power, $P_T(W) = P_{solar} + P_{wind} + P_{hydro}$ (2)
These are the individual power equations and total power equation [19].
Now, Available hydropower, P_{hydro}= 230 MW.
If 50 siemens 2.3MW wind power turbines are installed then,
Available Wind power, P_{wind}= 115MW
If 4000 module of rating 250wp and 15.50% efficiency it covers 6451 Sq.meter for 1 MW electricity generation.so if required no PV cells are installed then
Available Solar power, P_{solar} = 55 MW
From equation (2),
The total power, $P_T(W) = P_{solar} + P_{wind} + P_{hydro}$
= 55 +115+230 = 400MW

8. BENEDICTION FOR KARNAFULI HYDRO POWER PLANT

Electricity production from hydroelectric sources (% of total) in Bangladesh was 3.92 as of 2010. Its highest value over the past 39 years was 27.93 in 1976, while its lowest value is 2.92 in 2015. It indicates that electricity production decreases every upcoming year which should be stopped by using hybridization. Karnafuli hydro power plant is a base load power plant. During winter season water flow rate decreases creating intermittency in power generation which can be avoided by the efficient uses of storage water. Pumped storage method can be deployed and power will be supplied from wind extracted by wind turbine. A large number wind turbine and solar PV cell can be deployed to harness energy from that region so that power generated combining hydro power, wind energy and solar PV cell can meet the peak load. BPDB trying to increase the production capacity of Karnafuli power plant from 230MW to 330MW. It can be easily possible if HRES implemented. Then Karnafuli power plant will be the only paradigm of hybridization of hydro power, wind energy and solar PV cell. Consequently, it will accelerate the power generation in CHT as well as diversify the establishment and expansion of industries in Bangladesh. Furthermore the power generated will also permit pumping of water to achieve widespread irrigation and drainage. The reservoir storage designed to prevent serious flood has already saved the city of Chittagong from severe damage. Fishing in Kaptai reservoir annually produces more than 7,000 tons of freshwater fish. Right above the dam there is the unending vista of a smooth sheet of water up to all conceivable corners of chittagong hill tracts made negotiable by launches, boats and other craft.

9. CONCLUSION

Hybridization using hydro power, wind energy and solar in CHT is one of the most emerging power system integration methods. It increases the reliability of RE exploitation instead of conventional sources and decreases GHG emissions. It resolves RE intermittency and influences the development of advanced power electronics interface technology for harvesting energy. If we go ahead as planned, it will be possible for all citizens to have access to power within 2021. It also creates a viable network for electricity generation and the government target to produce 10% percent of total power generation by 2020 from renewable energy will be fulfilled.

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8. NOMENCLATURE

Symbol	Meaning	Unit
P	Theoretical power	(W)
A	Area	(m^2)
ρ	Density	(Kg/m^3)
v	Wind velocity	(m/s)
H	Gross water head	(m)
Q	Flow of water	(m^3/s)
g	Gravitational force	(m/s^2)