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Powering-Up Charging Stations for the Hybrid Electrical Vehicles by Harvesting Wind Energy Using Modified Wind Belt System

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Abstract

Now a days conventional energy resources are getting depleted and their use are causing environmental degradation. This problem is overcome by switching to Non-Conventional Energy sources. But a main problem is the availability of such resource at desired place and in a desired quantity. So in this paper, emphasis is placed on the use of Modified Wind Belt (MWB) to harness wind energy as it doesn't disrupt natural processes unlike other energy sources, it is economic, portable and ecofriendly. This paper furthermore suggests appropriate modification in the wind belt system to power up Hybrid Electric Vehicle's (HEV) Charging Station. The need of this effort arises as the world is inclining towards using HEV and the approach and availability of charging station is a practical constraint in this area. This paper is aimed at providing possible solution to this issue.

Keywords: Wind Energy, Wind Belt, Modified Wind Belt, Wind mills, Wind Turbines, Hybrid Electric Vehicle, Charging Hubs, Charging Stations.

1. Introduction

As the awareness to green energy increases on a global platform, various kinds of renewable energy equipment are seen entering the global market on a daily basis. However, there are few innovations that stand out among others. These innovative equipment are the prospective weapons for fighting the huge energy crisis the world is facing today.

Switch-over to the renewable energy is a great stride towards green energy. Rising fuel rates and pollution have led to the rise in demands for Hybrid Electric Vehicles (HEV). Industry Week quotes, "By 2015 worldwide demand for hybrid-electric vehicles (HEVs) will hit 4.3 million units and double by 2020, according to The Freedonia, Group, a Cleveland-based research firm"[1] . Due to the unavailability of charging stations at desired locations on the highways and other routes have led to the decrease in popularity of HEVs. The obvious reason is the shortage in electrical generation and hence shortage in its supply. This concern leads us to analyze the possibility of using a Wind Belt to power-up these Charging Stations.

Wind Belt is one of such devices that hold a promising future in the renewable energy market. This device converts wind energy to electrical energy by means of a stretched membrane and few magnets located within the proximity of coils- an Electromechanical Transducer. A wind belt is generally used for catering to small scale energy needs. A conventional turbine can do the same work, however the cost of establishing and high losses of energy due to friction and maintaining a wind turbine is an expensive and cumbersome task. The paper proceeds as follows:

This paper discusses the need to adopt renewable as the future energy resource and need of HEVs. Constraints on the HEV charging stations are put forward and various possibilities are discussed followed by the analysis of Shawn's Wind belt. The demerits of Shawn's Wind Belt are removed in the subsequent section of the paper. Further, the paper discusses a plan of establishing a MWB powered charging station for HEVs as a probable solution to the above mentioned problem. This section is followed by the advantages of MWB system as an implementation in the charging station of HEVs. The demerits and suitable corrections are also suggested. Future modifications and its probable implementations are also discussed in this paper

2. Background

2.1 Energy Scenario in India

The rate of consumption of fossil fuel is alarming and it will soon exhaust. The conventional sources, though economic, are not equally eco-friendly. As per the World Energy Council, the following is the present state of the nation in generation capacity (Data as on June 30th, 2011) [2]:

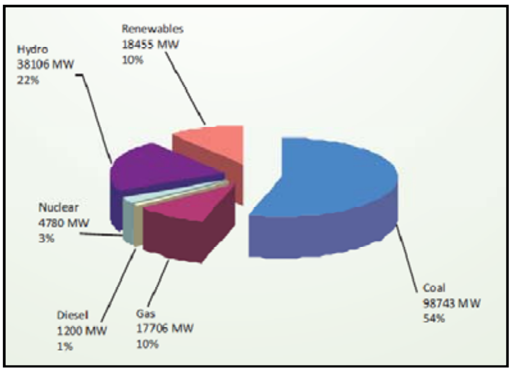

Figure 1: Generation Capacity India (2011) [2].

According to WEC an estimate, coal contributes maximum i.e. 54% of the total installed capacity of India where gas contributes to 10%, diesel 1%, nuclear 3%, hydro 22% and other renewable including wind contributes to 10% only, as shown in the Figure 1 [2]. Moreover, IEA (International Energy Agency) report states that 80% of India's energy requirement is met by fossil fuels itself. Due to this the fossil fuels are getting depleted at a very fast rate.

So, India should end its dependence on fossil fuel and consumers should be more disciplined in their use of subsidized fuel. India and countries of Southeast Asia are looking at ways of reducing their dependence on fossil fuels whose rising prices have acted as the biggest deterrent to global economic growth and development and the need arises to harvest energy from available renewable energy sources like nuclear, solar, tidal, geo thermal, hydro and wind. As the concern for eco-friendly and sustainable energy resource rises, the energy sector is shifting towards renewable, which is contributes to mere 12% of the total [3].

2.2 Renewable Energy Sources

The renewable sources constitute of Wind, Solar, Hydro, Geothermal, Biomass, Tidal, etc. With some or the other disadvantages, especially cost, these resources are not well realized as a commercial generation method. Indeed Wind energy is easier to harvest as the constraint of sun, location of geysers, availability of biomass and Tides is not there. Wind energy has the constraint of the uniform speed and poor efficiency of the wind turbines [4].

2.3 Wind Energy at a Glance

Wind power has been used as long as humans have put sails into the wind. For more than two millennia wind- powered machines have ground grain and pumped water. Wind power was widely available and not confined to the banks of fast – flowing streams. The wind wheel of the Greek engineer Heron of Alexandria in the first century AD is the earliest known instance of using a wind- driven wheel to power a machine [5]. The first windmills were used in Iran at least by the ninth century and possibly as early as the seventh century [6]. The use of windmills became widespread across the world [7].

In July 1887, a Scottish academic, Professor James Blyth, built a cloth- sailed wind turbine in the garden of his holiday cottage in Marykirk and used the electricity it produced to charge accumulators which he used to power the light in his cottage [8]. Later on this wind turbine was modified to generate electricity on large scales.

2.4 Disadvantages of Wind Energy:

1. Wind turbines generally produce a lot less electricity than the average fossil fuelled power station, requiring multiple wind turbines to be built in order to make an impact.
2. Wind turbine and wind mill both are very expensive and costly to surrounding wildlife during the build process [9].
3. They create noise pollution similar to a small jet engine [9].
4. The disposal or recycling of old towers and turbines poses another challenge to the environment.
5. One potential disadvantage of wind energy is the unanswered question about whether the electricity produced by wind energy is worth the cost. Wind towers and turbines are usually expensive and we don't yet know how many years they may be expected to operate before replacement is needed [10].
6. One significant disadvantage of wind turbine is the large amount acreage needed for installation. According to estimate 100 kW generation capacity wind farm would require 5 acres of land with 0.25 acre per installation [11]. The installation of wind farm is also not suitable in areas which are prone to natural calamities.
7. Wind turbines can cause problems with television reception and cause interference to weather radar installations [12].
8. Some of these problems were overcome by the introduction of Wind Belt by Shawn Frayne in 2007 [13].

2.5 Shawn's Wind Belt

At present a lot of research is being done to efficiently harvest wind energy. Several designs for wind turbines have come up that improves the efficiency, but not to significant values. The focus then shifts to develop a better means that can face the winds and effectively harvest wind energy. Effectiveness here stands for efficiency of the combined system in conjunction with the cost of the device. Shawn Frayne in 2007 developed a Wind Belt [13].

It consists of a fluttering belt and a small permanent magnet attached to it. A coil is fixed near the magnet. The relative motion between the magnet and the fixed coil develops an EMF across the coil. The flutter is caused by the wind [14]. A load can be powered by this generated EMF. The major disadvantage of this setup is that the power developed is very less and is available for the time wind flutters the belt. The power generated by the wind belt varies from 3W to 10W at varying wind velocity [18]. On the other hand it is very economical and easy installation.

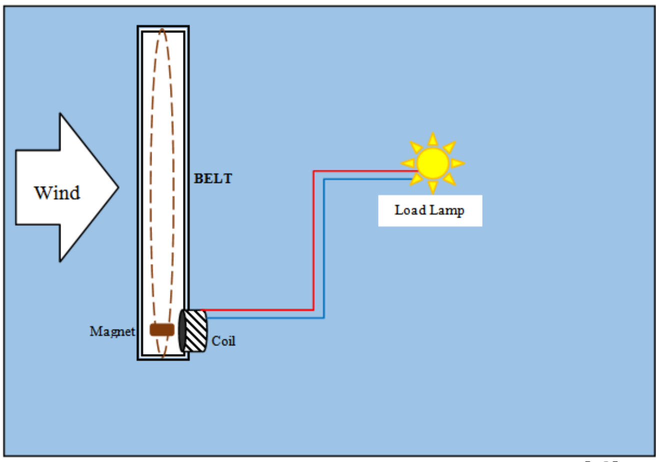

Figure 2: Schematic of Shawn's Wind Belt [13]

3. Proposed Solution- Modified Wind Belt for Hybid Vehicle Charging Stations

In this paper a modification is suggested to the setup of the original Shawn's Wind belt and try to eliminate some of the demerits of the same. Firstly a modification is provided for the wind belt and then it is implement for powering the HEV Charging Stations.

To the existing setup of Wind Belt, firstly a power electronic circuit is added to convert the discontinuity of supply to a continuous regulated supply. Further, a battery and an inverter is added to get a desired regulated AC output and store the generated electricity for off-peak period. The combined system is suggested to be called as Modified Wind Belt (MWB) and it consists of a wind generator (Wind Belt) and a Power Management Unit (PMU) to store and condition the generated energy. The wind generator designed utilizes aero-elastic flutter to convert wind energy into electrical energy, and is similar to the wind belt that was developed by Humdinger Wind Energy. Further, this system can be implemented as an array of wind belt to obtain required power.

Design

The MWB consists of the following:

1. Aero-Elastic Flutter
2. Permanent Magnet
3. Helical wound Copper Coil
4. Rectifier and Filter

5. DC-DC Converter
6. DC Battery Charger
7. Battery
8. DC-AC Sine Wave Inverter

The design of the MWB is as follows:

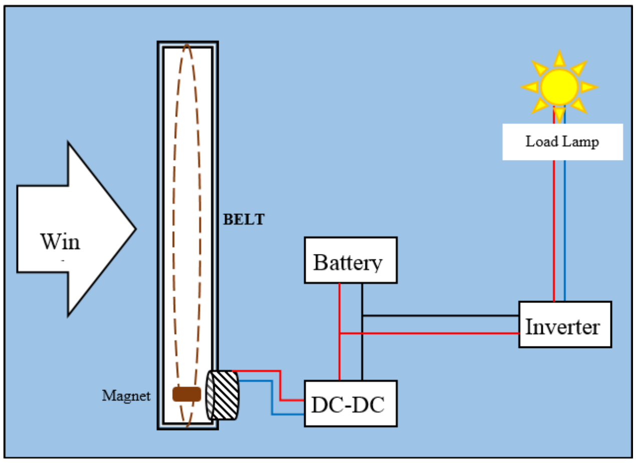

Figure 3: Modified Wind Belt System.

Working

The MWB works as follows:

a. The wind forces the belt to flutter.
b. A coil is fixed on the frame and the relative motion of the permanent magnet (fixed on belt) causes the flux to change and hence produce EMF.
c. The generated voltage is passed through the rectifier-filter and converted to DC.
d. The voltage level of the input is stepped to 15 Volts through a DC to DC converter.
e. This voltage is used to charge a battery (12 V) and can supply a DC load.
f. The supply from the storage battery is fed to the sine wave inverter to get a desired frequency, low-harmonic AC output.
g. AC Load is connected through the inverter.

Selection of various components:

The following are to be designed according to the requirement:

a. Coil: suitable number of turns for required EMF.
b. Permanent Magnet: suitable strength for required EMF.
c. Rectifier Bridge: should have low voltage drop.

d. DC to DC converter: suitably designed to step up/down the voltage to 15 Volt DC.
e. Inverter: should be a sine-wave inverter so that it produces lesser harmonics [15]. The inverter must be designed to give 50 Hz /60 Hz power frequency.

MWB implementation in an Array for Large Power Requirement.

The MWB is equipped with very efficient power circuit but lacks the total generated power if single unit is considered. Thus, it is required to operate several such systems to work in parallel and sum-up the total generated power multifold. This is done by making an array of MWB.

Voltage relation for electromagnetic induction in coil is given by [19]:

$$E = 2\pi fNAB$$

Where:
E: Maximum value of EMF Generated (in Volts)
f: Frequency of flutter (in Hz)
N: Number of turns in a Coil
A: Area of the Magnetic Path (Core) in m2
B: Magnetic Field Strength of the magnet (in Tesla)
The frequency is related to the belt velocity as:

$$f = \frac{v}{d}$$

Where:
v: velocity of wind belt (in m/s)
d: maximum flutter distance (in mts)
r: radius of coil (in mts)
The modified E.M.F. equation is:

$$E = 2\pi \frac{v}{d} N(\pi r^2)B$$

The above equation shows that EMF can be varied by change in wind velocity (v), area of coil (A) and maximum flutter distance (d).

According to Beaufort scale for wind velocity, if the EMF is calculated for “Fresh Breeze”, that is number 5 on scale, the wind velocity varies from 8.1 m/s to 10.6 m/s. With this velocity and r= 2.5 cm, d= 5.0 cm, N= 500 turns, and B= 0.02 Tesla, the value of EMF generated varies as shown:

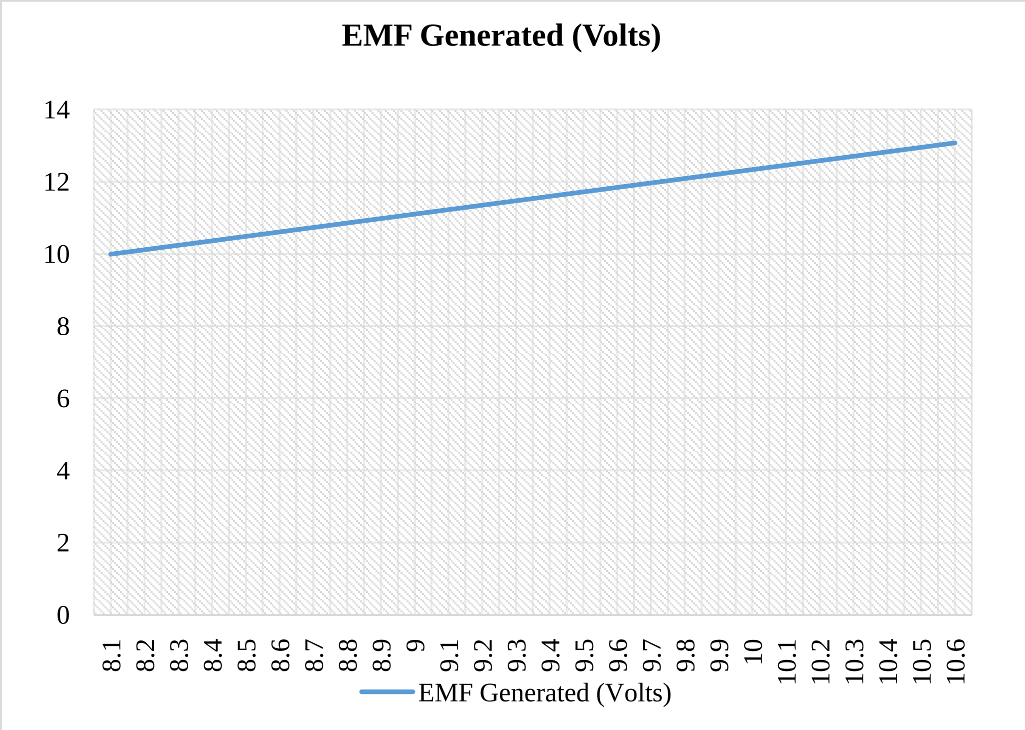

Figure 4: EMF Generated vs. Wind Speed.

The EMF is generated from 9.98V to 13.07V for the above mentioned speed variation.

The corresponding EMF_{rms} will be:

$$Erms = Ecos(wt)$$

Where:

$$w = 2\pi f$$

This array of MWB will be mounted along the highways at desirable positions to set-up the Charging Station for HEV.

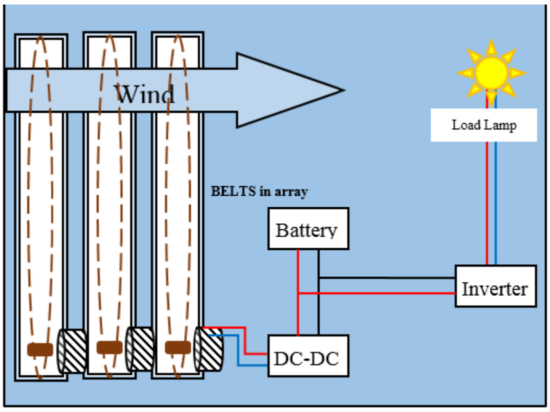

Figure 5: Wind Belts in Array [16] and Modified Wind Belt System in Array.

The parallel connection of MWB is advised with a series diode that limits the backward flow of current during off peak hours. Above (right) is the schematic of an array of MWB.

Design of MWB Powered Charging Station

The following block diagram suggests a general design of the MWB powered charging station:

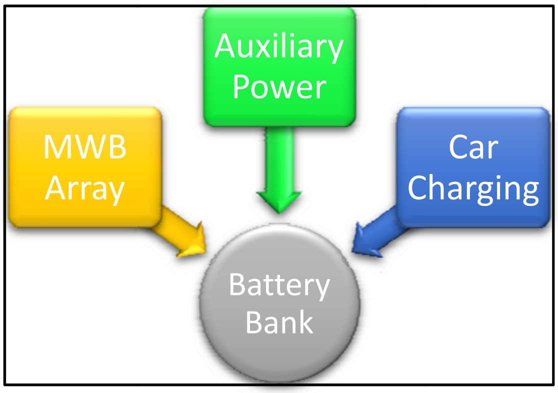

Figure 6: Block Diagram Representation of Charging Station.

The MWB Arrays feed the battery bank installed at the Charging Station. The consumers plug-in to charge their HEVs.

Advantages of MWB

On analysis we observed the following advantages:

a. Each unit of wind belt is made up of very low cost components as described below:

a.	Chassis	:	100/-
b.	Aero-Elastic Flutter (1 m)	:	20/-

c. Permanent Magnet	:	50/-
d. Coil with core	:	50/-
e. Rectifier and other circuit	:	50/-
Total	:	270/-

(Cost in Indian National Rupee)

Thus, it is a very economical installation.

a. MWB does not produce low frequency noise hence it can be placed very near to the populated areas.
b. MWB has components that are easily available and economic.
c. The maintenance of MWB is easier than the conventional Wind Turbine.
d. A constant DC or desired AC voltage can be tapped out from the power circuit of the MWB system.
e. The placement of the array on the Highways ensure two advantages:
    a. MWB will always be in operation as the vehicles (HEVs as well as Internal Combustion Engine (ICE) run vehicle) will always ply on the roads and highways.
    b. The transmission losses will be reduced when the installation is near the charging station.
    c. The power may also be used to power-up the street lamps.

Demerits of MWB and suitable corrections/modifications

The MWB system is advantageous but has few demerits as well. These are pointed below with the measures taken.

a. The power developed is less but we can connect array to obtained desired power.
b. The reliability of wind flowing or cars plying is never hundred percent but we use a power electronic circuit in conjunction with a battery to obtain continuous uninterrupted power.
c. Flux weakening of permanent magnet is an aging phenomena and needs to be replaced but if the magnet is made of rare earth metal, the effect of aging is considerably minimized and also the magnetic strength is also enhanced.
d. The additional power electronic circuit is involved that raises the cost but also accounts for the continuous and constant power supply.

4. Future Modifications and Proposed Application of MWB

The Modified Wind Belt system can also be put to the following implementations:

a. The MWB system can also be used for auxiliary applications such as powering up of Wi-Fi outdoor routers and switches [17].
b. Powering up of traffic lights on crossings.
c. Powering up of radar speed guns to monitor over speeding.
d. Powering up of SOS call booths located at desired locations on highways.

e. Powering up of aviation beacon on the telecommunication towers located in the vicinity of the MWB array

5. Conclusion

The paper provides a possible solution to establishing a charging station by implementing a wind belt whose performance is enhanced by the use of power electronic circuit and battery bank. Its low cost installation makes it affordable. There is no health hazard as no low frequency noise is generated and hence this can be setup very near to the population. The reliability of operation is increased by installing the setup on the highways where continuous traffic creates appreciable wind velocity (more than 8.1 m/s). This setup will be connected in an array and power-up the charging station of Hybrid Electric Vehicles. The only drawback of the system is that like wind turbines, all of the wind energy is not converted to electricity but in this case the modifications in the belt design, funnel shape [20] and material of magnet can increase the efficiency.

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