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A review of feasibility study on solar operated auto rickshaw as sustainable transport system for urban and rural areas

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Abstract

Today's demand for energy, coupled with steady progress in the technologies of renewable energy opens-up novel opportunities for the utilization of renewable energy resources. Solar energy is the most rich, infinite and dirt free of all the renewable energy resources available everywhere. In this research, an attempt has been made for making the best use of solar energy regarding the transportation of passengers and goods as well as for the reducing the emissions from the vehicles which are especially being used for commercial transportation by developing a solar-operated auto rickshaw as a sustainable transport for both rural as well as urban areas.

Keywords: Three-wheeler, emission control, e-rickshaw, e-transportation, solar panels

Introduction

Global environmental concerns and the escalating demand for energy, coupled with steady progress in renewable energy technologies, are opening up new opportunities for utilization of renewable energy resources. Solar energy is the most abundant, inexhaustible and clean of all the renewable energy resources till date. Recognizing the importance of energy independence for holistic socio-economic development, the Government of India has over the years made consistent efforts to develop power infrastructure in the country. In view of concerns related to environmental sustainability and the need for decarbonisation, the Government has also initiated focused efforts to increase the share of renewable energy (RE) in national power & transportation system. India like other developing countries is characterized by its rising population mounting urbanization and motorization. As Indian cities have grown in population, they have also spread outward. A lack of effective planning and land use-use controls has resulted in rapid, rampant sprawl extending beyond old city boundaries and into the distant countryside. This greatly increased number and length of trips for most Indians forcing further reliance on motorized transport^[1]. Most of the urban and semi urban commuters use motorized three wheeler called auto rickshaws for local transportation. Auto rickshaws are small, three-wheeled vehicles which are used extensively in many Asian countries for transport of people and goods. The vehicles are small and narrow allowing for easy maneuverability in congested Asian metropolises. In India, auto rickshaws are commonly used as taxis, as they are very inexpensive to operate. Many people depend on auto rickshaws for their livelihood.



Fig 1: Three-wheelers on the road

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Most of the cities and towns in India are highly polluted. The main reason is the air and noise pollution caused by transport vehicles, especially petrol and diesel-powered two- and three-wheelers. In India, there are presently millions of petrol-powered two-wheelers and diesel-powered three-wheelers and their population is growing at a rate of about 15% per annum. Besides being a major hazard to people's health, these machines are guzzling huge amounts of petrol and diesel for which the country has to pay dearly in foreign exchange outflow [2]. Recent changes to four-stroke engines as well as those powered by diesel, compressed natural gas (CNG) or liquefied petroleum gas (LPG) reduce the pollution and greenhouse gas emissions.

However, because of the large number of vehicles emission of such vehicles is still an important issue and also these are non-renewable energy sources. Some studies about converting an internal combustion engine (ICE) rickshaw to an electrical or fuel cell rickshaw have been done recently [3]. An improved electric cycle rickshaw can provide a non-polluting and silent transport system for urban and rural areas of India. It can also provide large-scale employment to millions of urban and rural poor. Nimbkar Agricultural Research Institute has developed two types of rickshaws – improved pedal cycle rickshaw and motor-assisted pedal cycle rickshaw – the details of which are given in this article. It is shown that these rickshaws can provide a safe, environment-friendly, energy-efficient and cost-effective transport system in cities and towns of India. Commercialization, technology, social and policy issues are discussed for large scale introduction of these rickshaws. E-rickshaw was introduced in New Delhi during Asian Games 2010. Presently more than 1,00,000 e-rickshaws are plying on New Delhi roads. An e-rickshaw consists of an electric motor of 500-1000w and a rechargeable battery of 150-200Ah. E-rickshaw run about 80 km for 8 hours charging of battery. Though it has got number of advantages over engine rickshaws, it has got some limitations also. It requires 8-10 hours' Continuous electric supply consuming 10 KW to charge the battery fully. If there are 1000 vehicles plying on the roads of a city, to recharge these vehicles 10 MW power is required which will be a burden on Electricity Corporation as there is huge gap between demand production of electric power by all means already.

Most of the power generated in auto rickshaws is produced using fossil fuels, which emit tons of carbon dioxide and other pollution every second. More importantly, fossil fuel will eventually run out. In order to make the development of our civilization sustainable and cause less harm to our environment, people are looking for new source of substitute clean energy. Because of the increasing demands in clean energy, the solar energy is one of the fastest growing forces in the market. Nowadays, there are several major directions for solar technology development. For example, photovoltaic systems directly convert the solar energy into electrical energy while concentrated solar power systems first convert the solar energy into thermal energy and then further convert it into electrical energy through a thermal engine.

Solar photovoltaic energy

Generation of electricity from solar energy can be achieved in two ways. In the first, solar energy is converted directly into electricity in a device called a photovoltaic (PV) cell. In the second, solar thermal energy is used in a concentrating

solar power (CSP) plant to produce high-temperature heat, which is then converted to electricity via a heat engine and generator. Both approaches are currently in use. The generation of electricity using PV panels is a worldwide phenomenon. Assisted by supportive pricing policies, the compound annual growth rate for PV production from 2003 to 2009 was more than 50% making it one of the fastest growing energy technologies in percentage terms. As of the end of 2009, the installed capacity for PV power production was about 22 GW [5].

Literature review

Most of the cities in developing countries are highly polluted. The main reasons are air and noise pollution caused by transport vehicles, especially petrol-powered two and three wheelers. For example, in India there are close to 18 million petrol powered two wheelers and about 1.5 million petrol and diesel powered three wheelers. Their population is growing at a very high rate of about 15% per annum [6]. There are guesstimates that close to 1 million cycle rickshaws ply on the Indian roads carrying about 3-4 billion passengers-km/year. In some cities they are the major means of transport. They provide employment to about 700,000 rickshaw pullers, are very manoeuvrable and are completely non-polluting and hence environmentally friendly means of transport. It is very unfortunate that deliberate policies in most of the urban towns have been made by the concerned authorities to phase out these rickshaws.

Although the petroleum based vehicle design is well suited to the environment in which it operates, it is a crude and inefficient design. Due to poor vehicle maintenance and the use of inefficient two or four-stroke engines with very little pollution control, these vehicles present a grave pollution problem in major Indian cities. N. Narender Reddy and *et al.* [7] proposed that the solar/battery electric vehicles is meant to match and exceed the conventional vehicle's performance but with a more intelligent and efficient design. Research work on electric and solar vehicles around the world is in progress. Many are trying hard to make these vehicles as alternative to petroleum based vehicles. Many of the researchers argue that the main reason for the air and noise is petroleum based vehicles [8-10]. It was found that Pollution from these vehicles is growing at a significant rate. Besides these vehicles recently electric rickshaws are being tried out which do not contain any pedal arrangement. So its driving speed is totally dependent on the charge of battery which diminishes gradually on use. When the batteries don't have enough charges these become inoperable. As a result, these require high motor and battery capacities that make them expensive. It was found that a recharging infrastructure is proposed for e rickshaws which will allow for the batteries to be charged using mostly renewable energy sources such as solar power and also consists of a central recharging station which supplies distribution points with charged batteries [10].

Ambassador T.P. Sreenivasan *et al.* [11], conducted research on "E-Rickshaws". E-Rickshaws are the latest entry in the Indian road and transport system. A flexible, non-polluting and affordable system, they have been playing a significant role in solving the last mile connectivity issue. Due to the absence of rules and norms, they have been largely operating very informally. While the licensing of E-Rickshaws has been given the nod by the Ministry of Road

Transport and Highways, the operation of this system is still ambiguous which has currently led to the ban order by the Delhi High Court. Richi Verma ^[5] conducted a study on recharging of E-rickshaws in New Delhi. It was found that e-rickshaws have allegedly been using electricity that is not accounted for. Power DISCOMS in Delhi alleged there is no knowing where e-rickshaw owners charged their vehicles, a majority of them simply tap power from streetlight poles and electricity lines. In the past two years, several e-rickshaw owners have been charged with power theft but in the absence of a policy on where and how e-rickshaws should be charged, DISCOMS claimed there was no way to keep a check on them. Before the high court ban on July 31, about 1 lakh e-rickshaws plied in almost all parts of the city. Since then, Delhi Police has been impounding e-rickshaws on a daily basis. "On average, e-rickshaws consume around 10 units in a day one unit of power is enough for approximately 10km. Most e-rickshaws run on stolen electricity, which is estimated to be Rs 18 Cr. worth of power in a month and Rs 216 Cr. in a year," said a DISCOM official. Prime Minister Narendra Modi took a ride of e-rickshaw before distributing 1,000 such rickshaws among the beneficiaries in the premises of Diesel Locomotive Works (DLW) on Sunday afternoon. He also interacted with a group of e-rickshaw drivers at a brief meeting on the occasion. Immediately after his arrival at the DLW ground the PM sat on an e-rickshaw and took a ride of the entire ground before his meeting with a group of 16 e-rickshaw drivers at a chaupal on wooden chaukis. These drivers will provide round the clock service to old age persons, pregnant women and differently abled persons at the railway station without charging any money.



Fig 2: Honourable P.M. in E-Rickshaw

Sagar Tatipurumala ^[12] also dealt with the problems of existing auto rickshaws and suggested use of hybrid vehicle to overcome the problems. Md. Abdur Rahim *et al.* ^[13] discussed about socio-economic & environmental impacts of battery driven auto-rickshaw at Rajshahi city in Bangladesh. Rajvanshi, A. K. Discussed about cycle rickshaw based on economic physical of the operator. Electrically powered vehicles represent an option to replace fossil fuel. Distributed charging stations are essential to ensure mobility. Charging stations not only charge electric vehicles' traction batteries, they also function as an interface between vehicles and the grid ^[14].

Gupta A. presented sensitivity analyses performed by exercising an electric vehicle model to understand relationship between customer based vehicle requirements (e.g. size, carrying capacity, weight, aerodynamics, 0-60

mph acceleration time, maximum velocity) to electric vehicle characteristics (Motor and battery specs.), energy consumption during different trips, and running costs for a trip ^[15]. Md. Sohel Rana *et al.* ^[16] conducted a study on 11208 battery operated auto-rickshaws running within study areas in Bangladesh and found that the energy was around 82.90 Megawatt of electricity per day to be recharged. The study also revealed that lower-middle and even middle income people of urban areas of Bangladesh since the mode of transportation by battery operated auto-rickshaws involved lower travel cost than other locally available transport modes as well as provided reasonable safety and comfort to the users during travel ^[17]. The air pollution produced by fossil fuel vehicles is nearly 70% ^[18]. Low-carbon mobility is possible with a combination of public transport, walk able cities, cycling, telecommuting and battery operated solar vehicles. Half of the daily vehicle commutes are less than 40 kilometres; 90% less than 110 kilometres ^[19]. Above literature review tells that, three wheeler rickshaws that ply on roads of India extremely convenient. They are everywhere, affordable and go places where a taxi cab cannot. It's common knowledge that in these two or four stroke engine vehicles most of the power generated is produced using fossil fuels, which emit tons of carbon dioxide and other pollution every second.

Though, an electric cycle rickshaw can provide a non-polluting, point-to-point and a silent transport system for urban and rural areas of India it has got some drawbacks like supply of continuous power supply increasing burden on power plants, limiting the distance to be travelled and decrease in speed of the vehicle when the battery keeps on discharging. Because of the increasing demands in clean energy, the solar energy is one of the fastest growing forces in the market. Hence, a research project has been undertaken to conduct Feasibility study on solar operated Auto Rickshaw as a Sustainable Transport System for Urban/Rural Areas being located between 160 and 18°27' North latitude and the geographic position favours the harvesting and development of solar energy.

Objectives

Objectives of this study are

1. To analyze spatially solar energy potential in urban/rural areas and to find actual solar radiation in different climatic conditions.
2. To find the actual efficiency and power availability of different types of solar panels various climatic conditions.
3. To conduct the socio-economic survey on auto rickshaws to find the total fuel consumption, total cost (Initial, operating and maintenance cost)
4. To conduct study on e-rickshaws to collect technical and economic information.
5. To develop a user friendly ecologically and economically viable solar auto rickshaw based on the study results.
6. Development of solar operated Auto Rickshaw Increase the utilization of natural power like solar energy.

Methodology

A case study based on socio economic and technical aspects will be conducted initially in Hyderabad Karnataka region for transportation system. Our researches mainly focus on transportation system in urban/rural areas (Kalaburgi, Bidar,

Raichur). In these cities, rickshaws are the major means of transport, later it will be extended to other areas. These rickshaws mainly depend on petroleum products, but fossil fuels emit tons of carbon dioxide and other pollution, and also fossil fuel will eventually run out. Various locations are selected in these cities and feasibility study of using solar vehicles. With the help of solar meter solar radiation is obtained in different climatic conditions and recorded for 2-3 years. Survey of the auto rickshaws is conducted to find the information regarding fuel consumption, total cost (Initial, operating and maintenance cost) and air pollution. The technical and economic data of e-rickshaws will be collected (Seating capacity, power requirement in kW, speed of the vehicle and safety aspects. A well-defined questionnaire is prepared based on technical and economic aspects. Various people related to public transportation system (Commuters, drivers, transportation system officials, auto rickshaw industry people etc) will be interacted with the questionnaires. Since, the actual efficiency and power output of the solar PV panels are less than actual ones, with the help of multi-meter and watt meter solar panel actual output and efficiency are calculated. After completing feasibility study a user friendly solar rickshaw is developed and prototype is prepared and evaluated.

Conclusion

This study shows the best method of utilizing the solar energy for passenger and good transportation purpose, also explores different ways for reduction of emissions from commercial vehicles by developing a user friendly ecologically and economically viable solar auto rickshaw as a sustainable transport for rural urban areas with an increase in utilization of natural power like solar energy having solar radiations in different climatic conditions.

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