Smart City – A Real Time Implementation Using Piezoelectric Sensors

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Abstract: It is a platform that focuses on a self-sufficient city/town managing the traffic, people and energy needs. A traffic jam is considered one of the biggest problems of many countries, this problem is solved by using a smart traffic system which consists of circuits and piezoelectric cells. The street lights will utilize power from the wasted mechanical energy from the vehicles that are travelling on daily basis. The mechanical energy from vehicles is stored and used in charging stations, which is used for charging gadgets and electric vehicles.

Index Terms **– Piezoelectric cells, traffic signal, streetlights, charging stations.**

1. INTRODUCTION

At present, there is a huge crisis of energy supply and achieving the goal of saving energy is of utmost importance. There is an urgent need to develop a renewable energy resource and find different energy harvesting methods. Harvesting energy from wind, solar, temperature gradient, vibration, etc. are common in today's standards but there is another method of harvesting energy from technologies such as photovoltaic, piezoelectric, etc., which is efficient. Energy generated because of the vibration of vehicles, this energy is not captured and not used. Using piezoelectric material, it harvests this wasted energy and can be used for various purposes such as intelligent street light system. This material is installed on highways for energy generation from the movement of vehicles and hence using this system for traffic control. Because traffic jam is one of the biggest problems of many countries, this problem is minimized by using a smart traffic system.

A few decades ago, the number of vehicles were small in towns and cities, but as the country developed and with urbanization, the number of vehicles was increasing exponentially. This led to daily traffic jams and to solve this, they used traffic lights on every crossroads. As the traffic light is automated and the green light opening time is the same for all lanes of crossroad, this resulted in the green light opening time being the same for the dense traffic and the low traffic. Many times, a lane that has low traffic became empty even though the green light open time has not completed and the other lane which has dense traffic is waiting, smart traffic light system is used for solving this problem. According to traffic density, this smart traffic light system changes its opening and closing time of traffic light. With the help of this self-sufficient system, street lights will not fetch power from the local grid lines as it uses the energy generated through a piezoelectric generator by the vehicles that are travelling daily. The system will charge during the daytime when no street lights are required and operate only during nights when it has been charged to last for the greater part of 12 hours of nightfall.

An electric vehicle charging network is introduced because the mechanical energy from vehicles is stored and it is used for charging electric vehicles. It is an infrastructure system of charging stations to recharge electric vehicles - including cars, neighborhood electric vehicles, trucks, buses and others. Some electric vehicles have onboard converters that plug into a standard electrical outlet or higher voltage outlet, and others use custom charging stations.

2. PROPOSED SYSTEM

A piezoelectric generator consists of one or more piezoelectric material. These materials are placed in the form of layers that are embedded in the ground for energy harvesting. The instalment of the sensors and master circuit into the road is uncomplicated and cost-effective. The piezoelectric sensors convert mechanical changes into electric voltage. The energy is produced by the motion of vehicles as shown in figure (1)

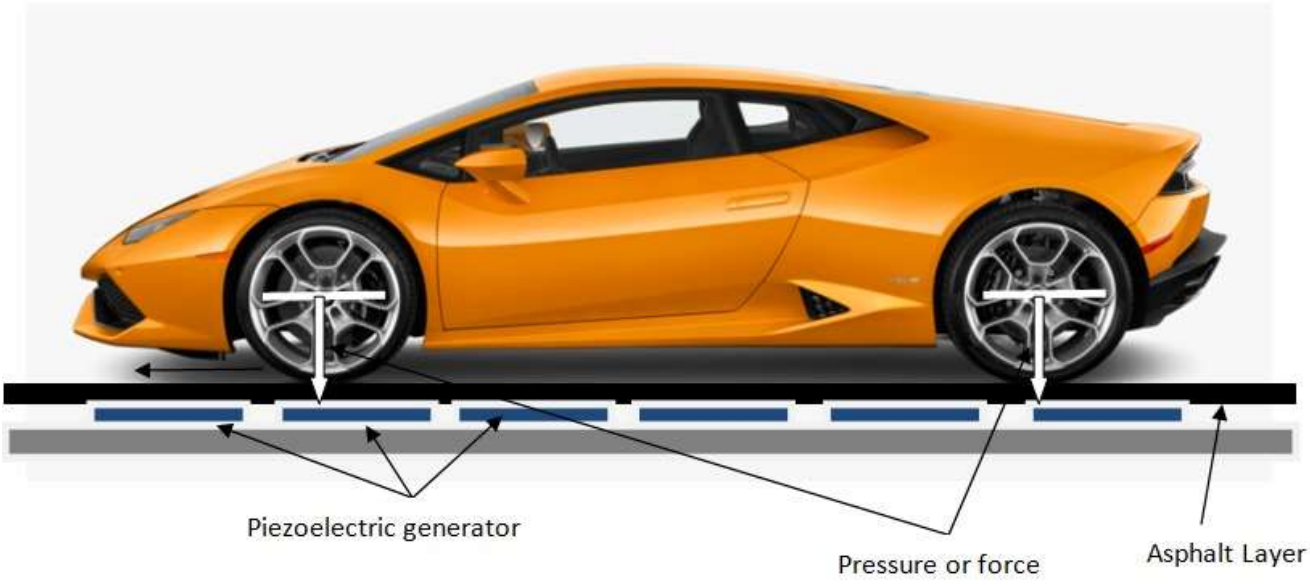

Fig (1) piezoelectric material embedded in the ground

The pressure exerted by the vehicle movement will determine the change in pressure in piezoelectric material and the energy generated. The effect can be mathematically represented by the following equation:

$$D = dT + \varepsilon^{E} \quad (1)$$

$$S = s^{E}T + d \quad (2)$$

Here,

Units	Quantity
D	Electric displacement
s	strain
d	Piezoelectric charge constant
ε^{T}	Dielectric constant at Stress(T)= constant
T	Stress
s^{E}	Compliance at E=constant;

The system can be applicable in the following areas:
• Smart traffic signal
• Street light
• Charging Station

2.1. THE SMART TRAFFIC SIGNAL

The set of two piezoelectric sensor will place on the road one is near the traffic light and another one is 200 meters away from the traffic light. In each set of plates, three sensors are placed in two rows. Firstly, two tar sheets are placed and three sensors are installed between the PCB (Printed Circuit Board) whose thickness is 3cm. This metal sheet is used as a basement that provides support to the sensor and increases the impact of the pressure applied by the vehicles. For amplifying and distribute the vibrations equally among the plates, a rubber bar is used. These rubber bars are installed in between the two sensors (covering with metal sheets) and at the end we used slightly bigger pieces

At present, traffic is either automated or controlled by a person, this resulted in numerous accidents and traffic jams. To solve this issue, a smart and intelligent traffic system is needed.

2.1.1. Proposed system

The main aim of this system is for solving the traffic jam problem and this principle is used for sensing the movement of people and vehicle with the help of piezoelectric sensors embedded on the roads and controlling the green light opening time for each lane according to the decision taken by the microcontroller used as shown in fig (2).

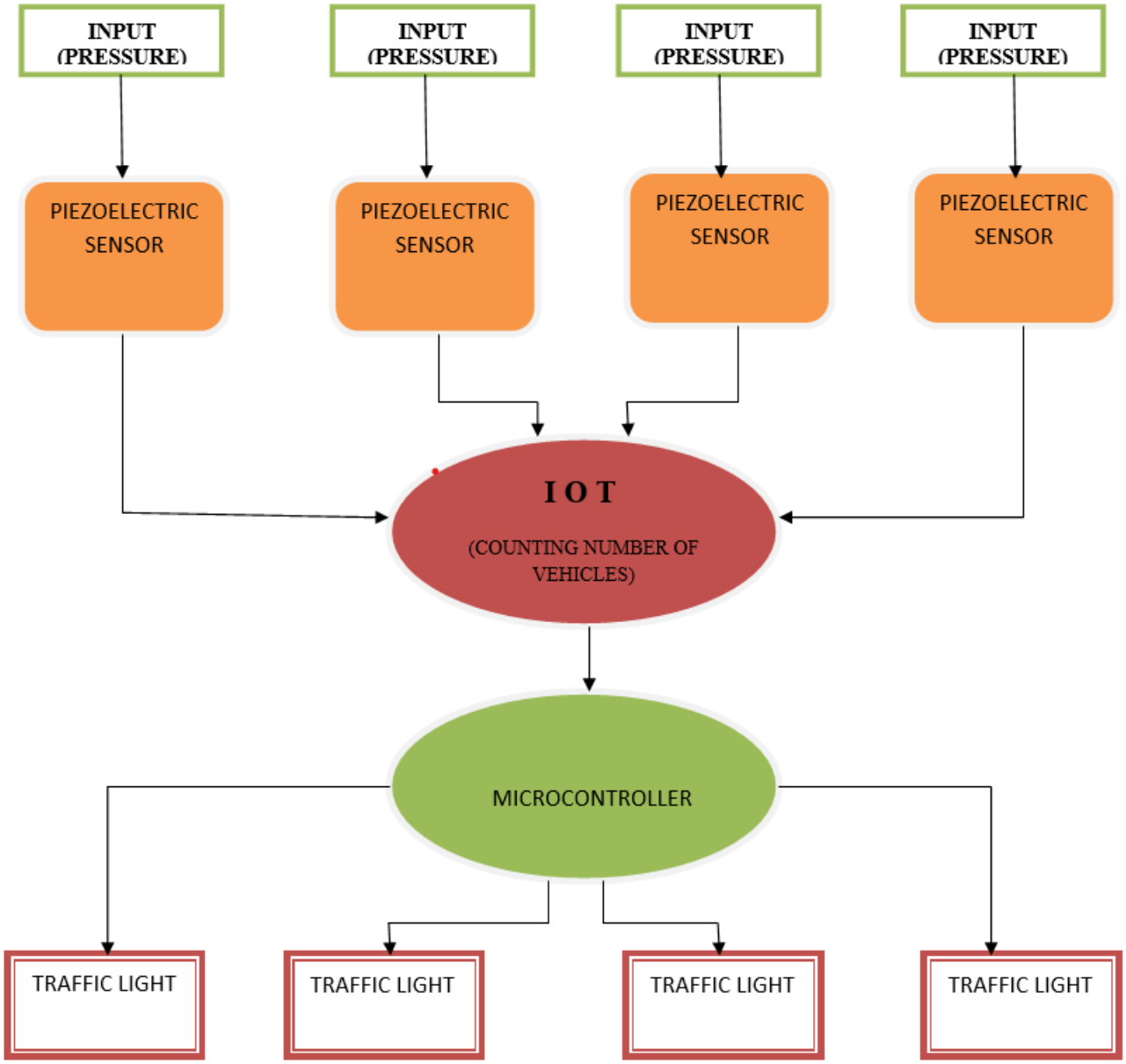

Fig (2) Block diagram of proposed system

There are many ways to detect and sense the movement of vehicles but the most reliable and cost-effective way is to use the piezoelectric sensor. It is cost-effective and it can be embedded in to the road surface easily for detecting the vibration. Cycle in signal changing remains the same as shown in the fig (3). A threshold value is set (with respect to the pressure generated from piezoelectric sensor in microcontroller) by which traffic is controlled Which mainly work on basis of these 3 conditions (based on a four-way intersection)

CASE 1: Pressure generated higher than the threshold value
If all the four-road having large no of vehicles, then the pressure generated from the four road will be higher than the threshold value. Then the four signals sequentially change, giving the four roads equal time to pass the intersection.

CASE 2: Pressure generated is equal to zero
If any one of the roads is not having any vehicles, then at that particular road will be assigned red signal. At the same time in other roads signal will change sequentially (likewise in case 1) until the corresponding pressure generated from the road is not equal to zero.

CASE 3: Pressure generated from all roads is less than the threshold value or equal to zero
If the entire four roads are having less/zero number of vehicles the signal assigned will be yellow. Any vehicle approaching the intersection at this time can watch around and cross at this particular time.

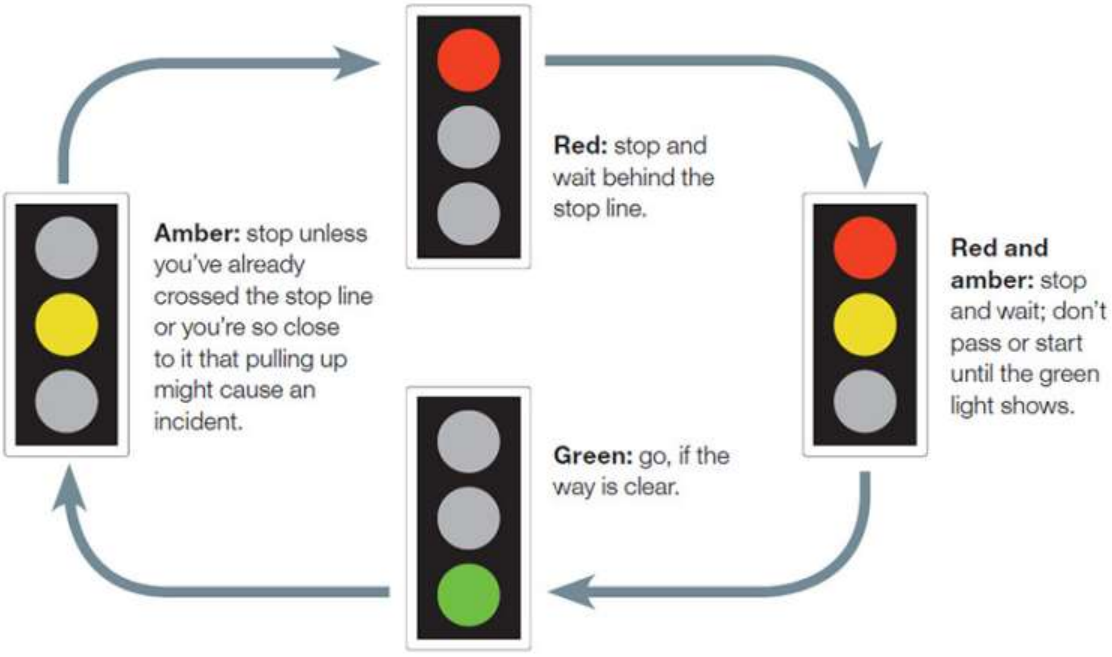

Fig (3) Traffic Light system

2.1.2. GRAPHICAL INTERPRETATION AND RESULT

The data obtained from MATLAB software is stored in the form of text files. Following 2-d graph as represented in the following fig. (4) is different for different cases. These cases are Perimeter that decide the nature of the curve are contact time, pressure applied and speed.

$$speed \propto pressure \quad (1)$$
$$speed \propto 1 / contacttime \quad (2)$$

And the time of contact and pressure will show the density of traffic in a certain row. Time of contact for pedestrian's, two wheeler's and four wheelers with different speed will be different and there will also be different.

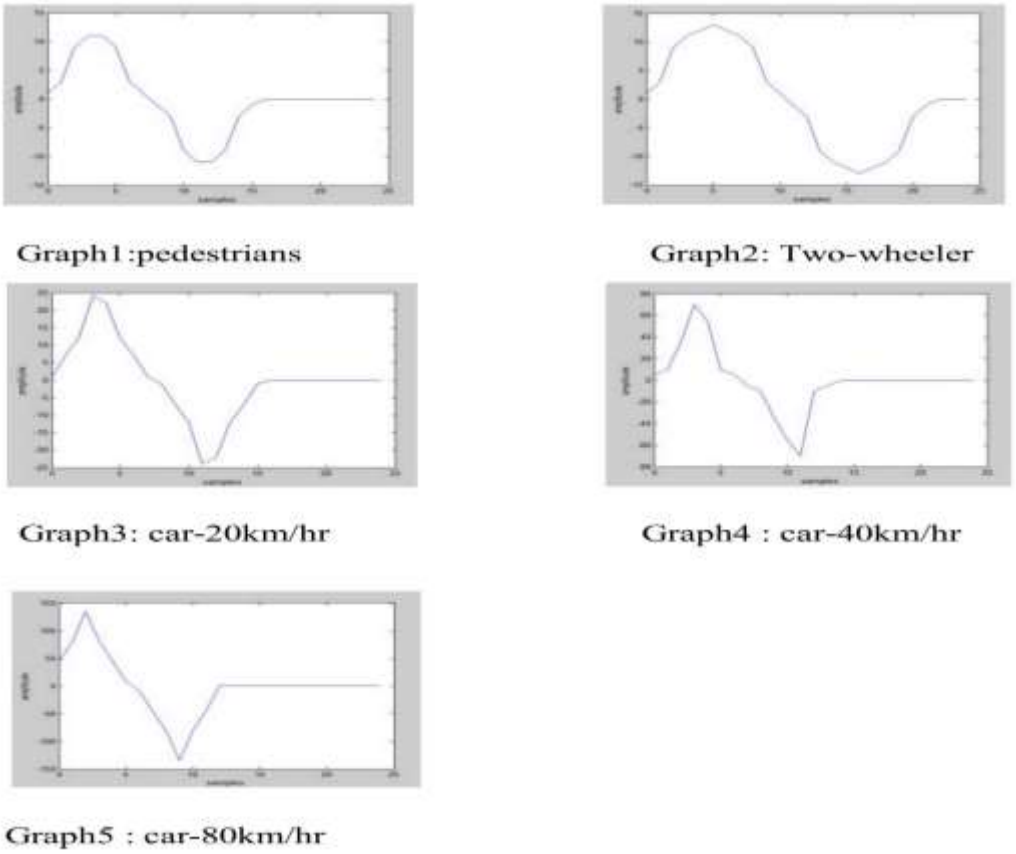

Fig (4) a sensors unit

2.2. IMPLEMENTATION OF STREET LIGHT

The piezoelectric materials are placed each other in series and covered by silica gel on either side to protect the plates from breaking due to pressure. As the plates are durable and strong, it is placed beneath the roads on which vehicles are meant to pass. The piezoelectric material produces ambient vibrational energy in the form of voltage when the vehicle exerts pressure onto the plates while passing through it. The prototype of the street lighting system is shown in Fig. 5.

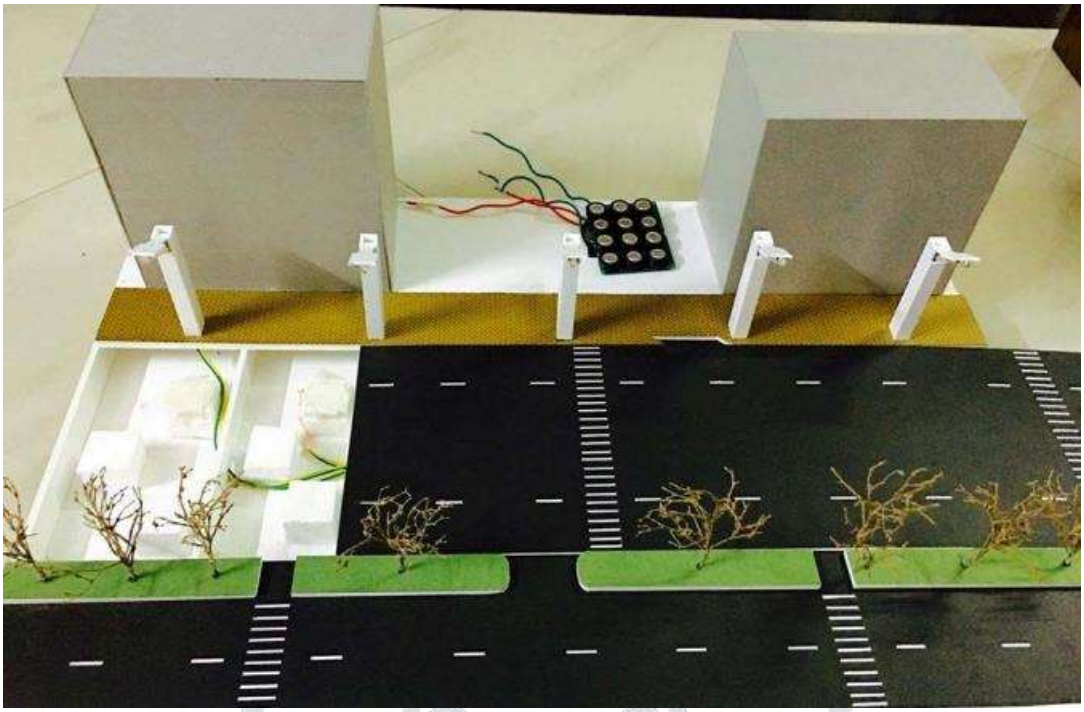

Fig (5) The prototype smart street lighting system where the piezo materials are placed under the slabs of the road.

As long as the vehicles are not always in phase with others, the piezoelectric material will not be in the same phase. A full-wave bridge rectifier circuits are introduced into the system to rectify the current being produced. This circuit is placed in each piezoelectric material and therefore making the current flow in one direction efficiently. However, there is a voltage drop of 1.4V but compared to the 5-15V produced by the piezoelectric materials in every vibration, the loss seems not so remarkable. Also, the rectified current is capable of charging the supercapacitor in record time.

Once the supercapacitors in series/parallel combination are fully charged, they can allow a voltage of 9V which is required to light up the lights for 25 Farads. The system will be lighting up LED lights instead of the more conventional light sources like sodium bulbs, etc. Each light has a power rating of 10 watts and is more efficient than any other light sources being used for such purposes. The lights are placed across each other in parallel since if one light is damaged by any external cause, the system will retain its integrity and keep working.

2.3 ELECTRIC VEHICLES CHARGING STATIONS

Electric cars are charged by plugging them into a charger that is connected to the electric grid and prototype charging station is shown in fig (6). EV chargers typically fall under one of three main categories:

Level 1 chargers use a 120 V AC plug and can be plugged into a standard outlet. Level 1 chargers do not require the installation of any additional equipment, unlike other chargers. These chargers are most often used at homes, and it typically delivers to two to five miles of range per hour of charging. Level 1 chargers take a lot of time to charge, but it is the least expensive option. Homeowners typically use these types of chargers to charge their cars overnight.

Level 2 EV charging stations are used for both residential and commercial charging stations. It uses a 240V (for residential) or 208V (for commercial) plug and it cannot be plugged into a standard wall outlet, unlike Level 1 chargers. This is usually installed by a professional electrician. Level 2 charging stations can also be part of a solar panel system. Level 2 electric car chargers deliver 10 to 60 miles of range per hour of charging. It is an ideal option for both homeowners who need fast charging and businesses who want to offer charging stations to customers because they can charge it as little as two hours.

DC Fast Chargers (also known as Level 3 charging stations) offer 60 to 100 miles of range with 20 minutes of charging for an electric car. As they require highly specialized, high-powered equipment to install and maintain, they are typically only used in commercial and industrial applications. Not all-electric cars can be charged with the use of DC Fast Chargers. Most plug-in hybrid Electric Vehicles do not have this charging capability, and some all-electric vehicles cannot be charged with a DC Fast Charger.

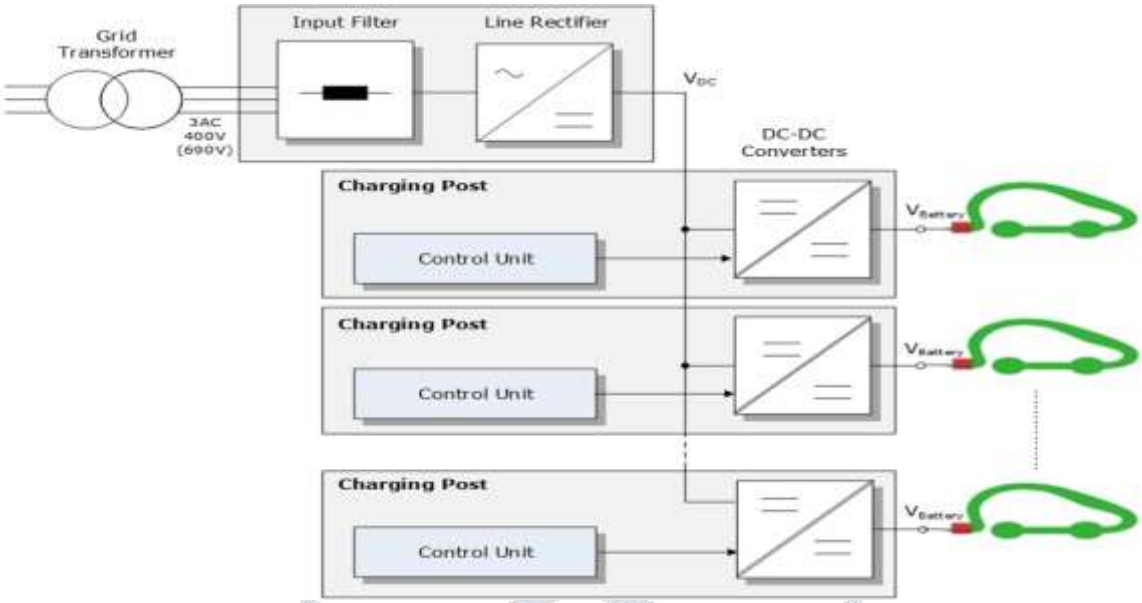

Fig (6) The prototype charging station

3. CONCLUSION

Renewable energy sources are more desirable because of the lack of more direct sources of energy. In this project, we make use of piezoelectric materials to generate practically usable electricity from wasted mechanical energy. Piezoelectric harvesters are becoming increasingly popular because the produced piezoelectricity now can supply up to10–100's of W of available power.

In all over the world there are many cross roads and people are wasting their time on crossroad due to traffic jam. Modern cities are using many new ways to overcome the problem of traffic problem and this project will help them to minimize their traffic problem.

The need for a real-time public transport information system is growing steadily. People want to plan their city commutes and do not like waiting for long hours, nor take a long route to reach their destination

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