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Recent Trend in an Electric Vehicle Warning System

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***Abstract*- Electric vehicle has an electric motor, the only drive source. The running noise of the electric vehicle is very quiet in nature than that of an internal combustion engine vehicle. For this reason, the pedestrian or the like is not aware of the approach of the electric vehicle. Therefore, in such a low noise vehicle, a notification or warning sound from a sound device such as a loudspeaker is caused to caution the pedestrian or the like around the electric vehicle. These warning systems are usually termed as "Electric vehicle warning sound". This paper discusses recent developments in designing of an electric vehicle warning sound technology by using patent document.**

Keywords: EV- Electric vehicle, warning sound, alert system.

I. INTRODUCTION

Growing demand from customers and government legislation [1] for more fuel efficient and less polluted vehicles has increased the making of both electric and hybrid vehicles. These vehicles are quieter than the IC engine vehicles. This has an advantage as there will be a reduction in noise pollution in city areas; however, the noise produced by IC engine vehicles is also an important warning signal for pedestrians, particularly those who are animals, visually decreased, and cyclists to indicate that a vehicle is approaching towards them. This is an important automobile active safety feature, thus has its own importance. Therefore, there is a concern that the lack of noise produced from electric vehicles may cause a safety risk for pedestrians, animals and cyclists. Consequently legislation is being announced to manufacture an electric vehicles with audible warning system that are made mandatory by government(s) over the world [1].

Popular Electric vehicle maker, M/s Tesla Motor's CEO Mr. Elon Musk believes that electric vehicles should produce a "pleasant sounding noise", but only when pedestrians or the likes are around [2]. Daimler recently said it's developing several electric-car tones for use in vehicles like the Smart Fortwo Electric Drive. That means everything from a "sonorous purring" for the Smart, to "huskier tones" in the SLS Electric Drive supercar [2].

With the beginning of the rapid spreading of electric vehicle technologies, many innovative research and developments are going on in the field related to electric vehicle warning sound systems.

II. ELECTRIC VEHICLE

An electric vehicle is propelled by at least one electric motors with the aid of electrical energy stored in energy storage device such as rechargeable batteries. The rechargeable batteries may be selected from the lithium ion battery, lead acid battery or Nickel metal hydride battery. Electric motors provide direct torque to the electric vehicle for smooth accelerator. The internal combustion engine in a gasoline vehicle is replaced by the electric motor in the electric vehicle. Along with engine, muffler, catalytic converter, tail pipe, fuel tank and clutch assembly are also removed. An AC / DC electric motor is connector to the conventional transmission system via plates and bolts. An electric controller is also added to control the AC / DC electric motor. A battery tray with series of rechargeable batteries are installed on the floor of the vehicle. A fuel lid is replaced by a charger plug lid with an electric adapter to charge the rechargeable batteries.

The electric controller takes direct current from the series of rechargeable batteries and sends it to electric motor in controlled manner. The transmission system takes power from the electric motors and delivers it to wheels of the car, same as in IC engine vehicles.

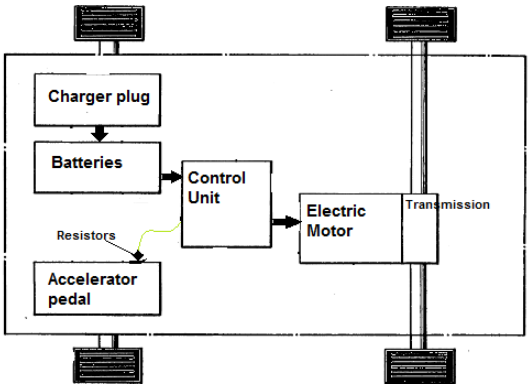

Figure 1. General Layout of Electric Vehicle

The electric vehicle concept began in the mid-19th century. The first practical electric car hit on road in the year 1884, an electric car invented by Mr. Thomas Parker [26].

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III. ELECTRIC VEHICLE WARNING SOUND

Electric vehicle warning sound is an important active safety factor for an electric vehicle. Active safety features are those that help to prevent or lessen the road crashes. A series of sounds are generated to warn pedestrians about the approach of electric vehicles, thus minimizing the possibilities of accidents. ECTunes has announced an intelligent pedestrian warning sound system for electric vehicles in the year 2010. An artificial engine sound is emitted to copycat the vehicle's speed and movement, allowing pedestrians to judge that a vehicle is moving and in which direction [3].

The pedestrian warning sound system has two loudspeakers one at front and one at rear, a control unit and the proprietary ECTunes sound core software, it is connected to the electric vehicle through analogue or CanBus integration. This solution is available "off-the-shelf" or as a customisable OEM solution [3].

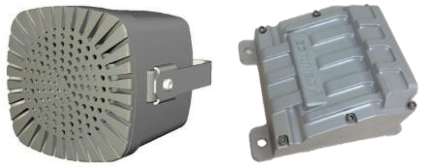

Figure 2: ECTunes 3" Automotive Speaker & ECTunes Control Box

IV. Technology Analysis and Categorization [4]

A patent is a techno-legal document granted by a government to a true applicant for a novel, inventive and an industrially applicable invention. Evaluating the patenting activities offers an excellent forecasting of the future technology in the marketplace.

To convey technology analysis in the field of an electric vehicle warning system, a subject concentrated patent search was carried out in European patent database famously known as “Escapenet” for the period of 1st Jan, 2000 to 12th Sep, 2015. Patent documents were downloaded and considered as the gauge factor to assess the technology trend (as patent documents are a rich origin of technical and commercial knowledge).

Further, the retrieved patent data set is analysed according to the technology focus and the relevant patents are filtered and categorised under following technology focus categories.

A. Software Transmission: This category describes the sound generation is controlled in specific algorithm and / or under specific circuitry method steps.

B. Electronic Transmission: Patents claiming the use of an electronic apparatus such as sensor, transducer, RF receiver etc. for generating artificial engine sound are classified under this category.

C. Electric Transmission: This category includes patents claiming use of an electric apparatus such as generator, vibration exciter etc. to generate artificial sound of the electric vehicle.

D. Mechanical Transmission: Patents which describe mechanical apparatus to produce artificial sound are categorized under this class. In addition, patents revealing various new mounting arrangements are also included in this category.

A total of sixty-seven relevant patent documents were found and some interesting and innovative patent idea were selected and grouped under above category to see the recent development in Electric vehicle warning system.

V. FORTHCOMING ELECTRIC VEHICLE WARNING TECHNOLOGIES

New technologies to increase the safety of road travel, relating to electric vehicle approach warning systems are in the pipeline. In the technology world, the latest advancement is only as good as the next thing coming into the market. The automotive industry is constantly bringing us new technologies, whether it is for safety, entertainment, usefulness or simply for pure innovation. Many new automotive safety technologies are either specifically built for safety, or at least have some sort of safety focus to them. Some of the latest car innovations in the area of electric vehicle warning system can overcome demerits of electric vehicle safety for the pedestrian, cyclist etc.

Based on what's currently being patented and tested some of the key future forthcoming electric car active warning safety technologies are listed below. The sixty-seven patent documents were studied and manually analysed to evaluate key forthcoming electric vehicle warning technologies.

A. Software Transmission

Some common approaches surveyed under software transmission, are by pedestrian detection in electric vehicle approach area [5, 6]; according to motor state, vehicle speed and / or accelerator position [7, 8]; according the position of gas pedal [9] and thereby specific algorithm are set to produce artificial engine noise.

Mr. Masao Noro an employee from Yamaha Corporation [10], invented a control unit (11) to control the signal processing unit (13) in such a way that the speaker array section (20) outputs the sounds in a direction displaced toward a foot path (2000) at an angle α with reference to the traveling direction of the vehicle (1). The direction and the angle is set by the driver according to the right hand drive or left hand drive electric vehicle with the aid of an operation section (7) (as shown in figure 4 and 5).

The above explained control unit (11) enables the sounds to be efficiently audible to pedestrians walking along the foot path (2000) without making sound pollution and disturbing others.

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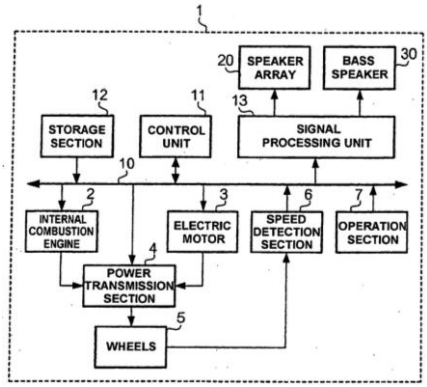

Figure 4: Block diagram describing a configuration of a vehicle with Masao Noro's invention

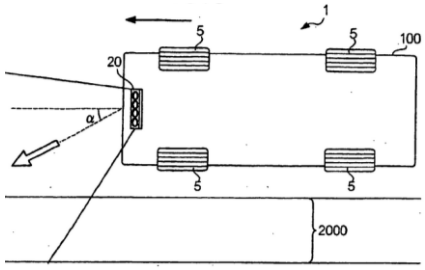

Figure 5: Describes directivity of sounds output from the speaker array at angle α

Mr. Paul Beringer Wilbur and Mr. Paulus Thomas Geantil [11], inventors work for APTERA MOTORS INC has developed a microprocessor-based computer controller (35). The controller (35) has a memory (37) where a factory-based music file(s) are saved. When a vehicle move forwards, the controller (35) gets signal from a sensor (41). Then the controller (35) sends signal to a sound emitter (59) to produce music as selected by the user (refer figure 7).

In an another embodiment of the controller (35), is design to send a signal to a traction motor (13) to produce a harmonic vibrations and thereby to emit sound without the need for a separate sound emitter (refer figure 8).

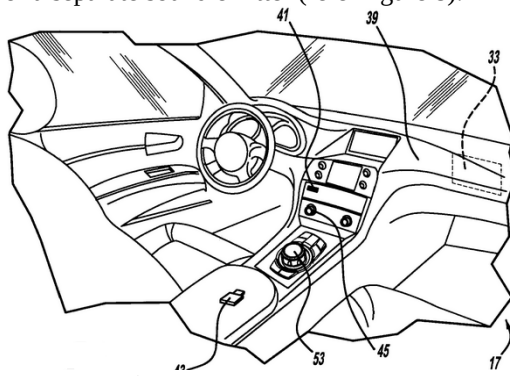

Figure 6: An interior of the automobile vehicle employing Paul and Paulus warning system

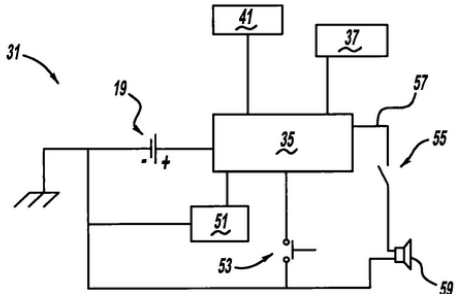

Figure 7: First embodiments of Paul and Paulus automotive warning system

The microprocessor-based computer controller (35) works with an algorithm as depicted in figure 9.

The sensor (41 or 51) senses the vehicle speed, if the vehicle speed is greater than 5 mph, the shifter position is also detected. Then if the vehicle is driving forward or reverse, the audio file will be activate and sound will be produce as explained heretofore. The invention also describes a flash external light indicator. The light indicator is also a useful warning sign to the pedestrian and is used along with the audio sound.

B. Electronic Transmission

All the patent documents enlightening the use of electronic device to produce and transmit the warning sound are grouped under the "Electronic Transmission".

Most of the patent approaches under electronic transmission are by using a sensor electronic apparatus. The sensor gadget is use to detect pedestrian, hazardous situations such as collision possibility, state of vehicle, vehicle speed, etc. and thereby producing the warning sound(s) [12, 13, 14, 15, 16].

Michael Fischer [17], describes a device (10) comprising a noise mixer (22) connected to a detection unit (24) and an amplifier (28). The noise mixer (22) receives the artificial noise form a microphone (16) provided in a sound collecting means (12) and sound providing the means (18). The microphone (16) and the sound generator (20) are electrically connected to an input of a noise mixer (22). The amplifier (28), mixes the generated sound signals to generate mixed signals (as shown in figure 10).

Michael Fischer device effectively produces artificial engine and / or exhaust sound without using the several algorithms as disclosed in the software transmission category.

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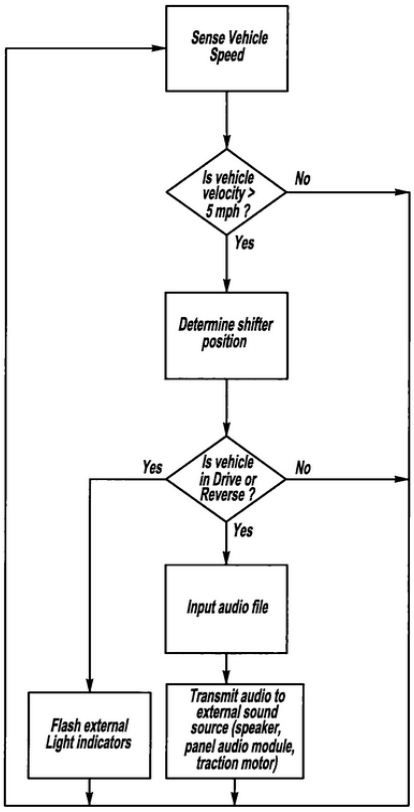

Figure 9: Flowchart for software employed in the Paul and Paulus controller

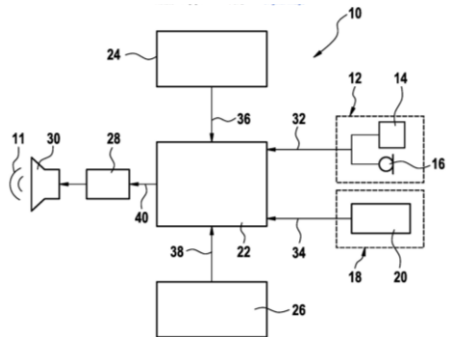

Figure 10: An apparatus for generating an output noise with a noise mixer

C. Electric Transmission

All the patent documents revealing the use of electric device such as electric generators (e.g. Faraday generators [18], oscillation generator and vibration exciter [19] to produce and transmit the warning sound are grouped under the "Electric Transmission".

A contact pickup device (3) invented by Mr. Akiko Nakatani [20], has been used as a sound generation device in an electric vehicle. The contact pickup device (3) is mounted to a housing of the inverter (I) for capturing oscillation of the housing so as to convert the oscillation into an electric signal. An amplifying device (5) amplifies the electric signal output from the contact pickup device (3), and a notification sound generating device (2) outputs a sound to the periphery of the vehicle based on the electrical signal output from the amplifying device (5) (as shown in figure 11).

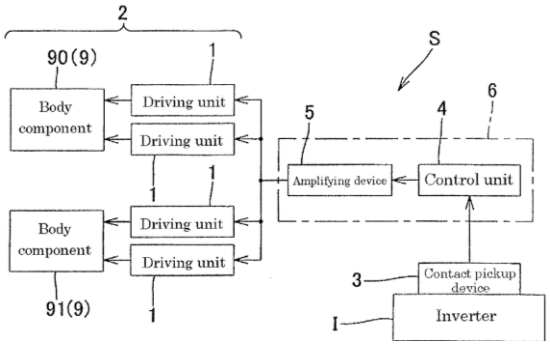

Figure 11: A block diagram illustrating a contact pickup device for noise generation

Concretely, as shown in FIGS. 12 to 14, the notification sound generating device (2) has an oscillation unit (1) constituted by consecutively installing a plurality of oscillators (10), and the oscillation unit (1) is mounted to the body component (9). The oscillation unit (1) is provided to the inner surfaces of front and rear bumpers (90) with the aid of locking means (90a). Thereby, by using inventor housing oscillation the desired sound in an electric vehicle is produced.

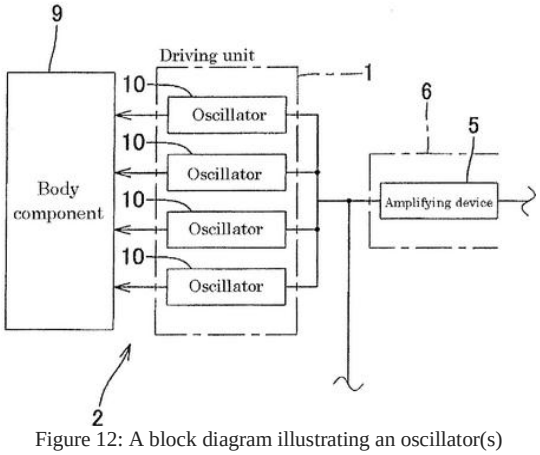

Figure 12: A block diagram illustrating an oscillator(s)

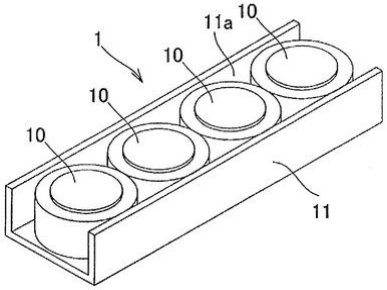

Figure 13: Illustrating the oscillation unit

Greenwood Jeremy and White David from Jaguar Land Rover LTD [21], discloses a system where the electric motor is energised to produce sound. The electric motor (1) has a rotor (2), a stator and a plurality of windings (4) for energising the motor (1).

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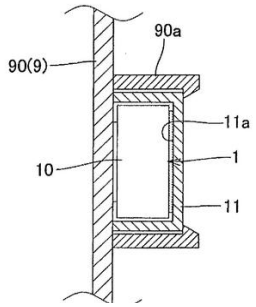

Figure 14: Mounting structure of the oscillation unit

The rotor (2) mounted within a plurality of stator pole pieces (3) (only one of which is shown in figure 15), each of which is provided with a stator winding (4). A current is supplied to the stator windings (4) by a generator (6). Thereby, the magnetic reluctance of the rotor (2) creates a force that attempts to align the rotor poles with the powered windings. In order to maintain rotation, adjacent windings are energised in turn.

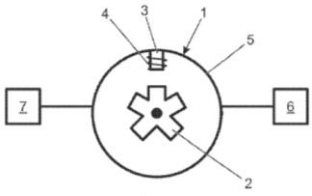

Fig. 1

Figure 15: A schematic view of a switched reluctance (SIR) drive motor for a vehicle

D. Mechanical Transmission

All the patent documents revealing the use of mechanical devices and mounting arrangements to produce and transmit the artificial warning sound of an electric vehicle are grouped under the "Mechanical Transmission".

Hideo Ogura [22], teaches a vibration generating device (56) for generating vibrations similar to the vibration of an internal combustion engine. The vibration generating device (56) is placed on the swing arm at a location between the electric motor (M) and a rear wheel (WR1) of the electric vehicle, which is a transmission path of an electric vehicle. Therefore, the drive force of the electric motor (M) is utilized and the vibration in accordance with the rotational speed (rotation number) of the electric motor (M) is generated.

A sound producing device (60) for producing a sound similar to the sound of the engine in accordance with the transmitted drive force is installed inside the swing arm at a position rearward of an axle of the rear wheel (WR). This provides vibrations and sounds for the electric vehicles.

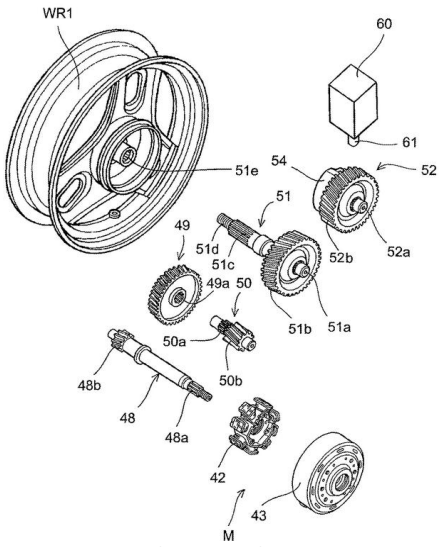

Figure 16: Illustrating a configuration of a speed reduction mechanism, etc., housed in the swing arm

The vibration generating device (56) comprises a drive side vibration generation unit (51), a driven side vibration generation unit (52), a third reduction gear (51 b) is meshed with a driven gear (52 b), a cam (54) and weights (55) each. The third reduction gear (51 b) included in the drive side vibration generating unit (51) and a driven gear (52 b) included in the driven side vibrating unit (52). The third reduction gear (51 b) and the driven gear (52 b) each serving as a rotating body generating vibration. It also comprises respective weights (55) implanted therein to positively lose the rotational weight balance of the gear. The third reduction gear (51 b) and the driven gear (52 b) are set so that when one of the weights (55) reaches the upper position in the figure, the other weight (55) may also reach the position corresponding to that of the one of the weights (55). This mechanism provides large vibrations by the two weights (55) combining rotation balance variations (as shown in figure 16 and 17).

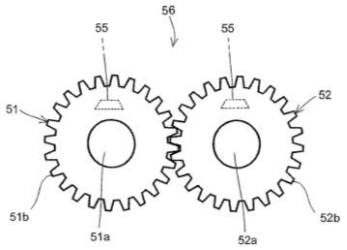

Figure 17: Vibration generating device

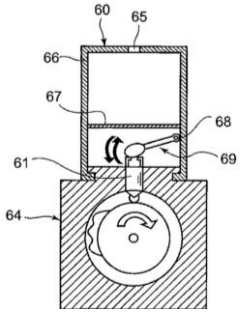

Figure 18: Sound producing device

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The sound producing device (60) is disposed at a position on the vehicle body upper side and above the driven gear (52 b). A columnar transmitting device (61) projects from the lower surface of the sound producing device (60) and has a lower end portion in constant contact with the cam (54) of the vibration generation device (56). The sound producing device (60) is configured to produce a predetermined sound through the reciprocation of the transmitting device (61). The transmitting device (61) reciprocates at a speed corresponding to the rotation speed of the driven gear (52 b) rotating integrally with the cam (54). Therefore, the sound emitted from the sound producing device (60) varies depending on the rotation speed of the electric motor (M) (as shown in figure 17 and 18).

The sound producing device (60) has a striking rod (69) and a film-like skin (67). The striking rod (69) supported swingably around a swing shaft (68) is installed in a housing (66). A film-like skin (67) is placed above the striking rod (69). As transmitting device (61) reciprocates vertically the striking rod 69 continuously strikes the skin (67) to sound (as shown in figure 17 and 18).

Mr. Tomoyuki Takewaka, Masahiro Akiba, Ryuji Akiba, Kazuhiko Tanaka and Satoru Shimizu inventors from Honda Motor [23], disclosed a vehicle approach notification device (40). The vehicle approach notification device (40) has an air opening (41), a ventilation passage (42) and a sound emission device (36). The air opening (41) and ventilation passage (42) formed in the vehicle body cover (32) for taking in air (1) from the atmosphere and for passing air there through as shown by arrow (2). A sound emission device (36) has a resonant chamber (44) and a resonant tube (45). The resonant tube (44) opens into the ventilation passage (42) in a direction intersecting the ventilation passage (42). The sound emission device (36) is fixed in a ventilation passage (42) and emits sound by means of an airflow that passes through the ventilation passage (42). The sound frequency is set from 100 Hz to 800 Hz, which is a frequency range of intake or exhaust sound of an internal combustion engine (refer figure 19 and 20).

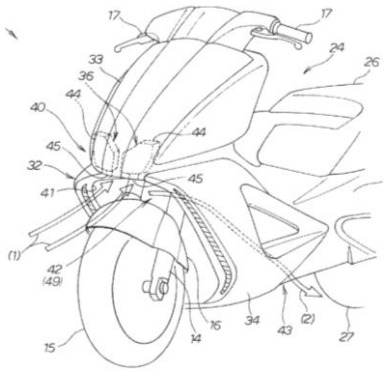

Figure 19: Vehicle approach notification device

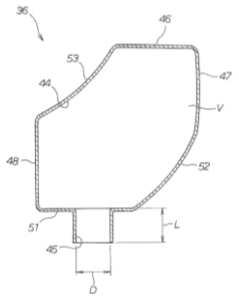

Figure 20: Cross-sectional view of the sound emission device

Rudolf Halbmeir; Audi AG [24], reveals the use of radiator fan to generate artificial sound of a vehicle purely drive by electric energy. A plate (3) is pivotally placed in an airflow of the radiator fan (1). A noise controller (GS) controls a radiator fan (1) and/or a device influencing a radiator fan noise for producing and emitting the variable vehicle-operation noise. The hinged plate (3) has a pivot axis (4). According to the direction of the double arrow 5 swivel and how far the plate (3) swung inside the radiator fan (1), more or less sound is generated (as shown in figure 21).

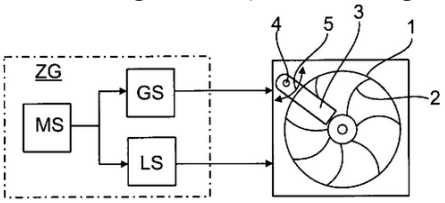

Figure 21: A simplified block diagram of a device for generating a vehicle operating noise with a radiator fan

The radiator fan (1) and plate (3) mechanism reduces additional and cumbersome construction of the noise generation device.

VI. CONCLUSION

Increasing road safety is unavoidable because it is so closely tied to human behaviour. This paper surveys the research on recent development in electric vehicle warning systems. The research and development in the field of the electric vehicle warning system is comparably new, as the electric vehicle concept began in the mid-19th century, but only sixty-seven patent documents on electric vehicle warning system were found. M/s Mitsubishi Electric emerged as a major innovator. Germany holds 28% of patent filing and has proven to be a major global for research and development in the field of electric vehicle warning technologies followed by the United States (19%) and Japan (17%). A detailed patent study of the electric vehicle warning system revealed that the major focus of research, has been in electronic and software technique to generate warning sound in the electric vehicle. However, these technologies are costlier, and therefore the electric vehicles are not affordable for the middle class people. M/s Audi AG and M/s Honda Motors research and development proven to be focuses on the mechanical apparatus to generate warning sounds. The mechanical systems and arrangements are considerably lighter and less expensive than the electronic or software noise generation, however, suffers from the disadvantage that at low drive speeds, where the additional noise is particularly needed. M/s

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Honda Motor, discloses a vibration generating and sound producing device which solves the problem of noise generation at low speed but are heavier and cumbersome in design. Hence there is a need to fabricate a system such that by using minimum additional components, still a reliable artificial warning sound can be generated in the electric vehicle.

The study identified very innovative technologies. M/s Audi AG, reveals the use of radiator fan to generate artificial sound of a vehicle purely driven by an electric energy, by adding a simple movable pin to the radiator fan. M/s Daimler AG, discloses an elastically bendable blade arranged such that it get excited by the airstream to vibrate and thus generates the desired noise in the electric vehicle. M/s Jaguar Land Rover discloses a system where the electric motor is energised to producing warning sound. M/s Yamaha Corporation, invented a control unit to control the area where the sound is directed. The direction and the angle are set by the driver, according to the right hand drive or left hand drive electric vehicle, this enables the sounds to be efficiently audible to pedestrians walking along the foot path without making sound pollution. M/s Honda Motors have developed a retrofitted sound emission device which acts as a resonator to produce artificial sound of frequency 100 Hz to 800 Hz, more or less similar to that of internal combustion engine. These technologies hold the possibility of contributing in making a safer electric vehicle.

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