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SMART STEERING SYSTEM

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Abstract—*The aim of this project is to design a new steering system for automobiles which will provide an ease in driving for various situations like U-Turn, Parking etc. Our project aims to provide hassle-free driving experience to the driver and remove the discomfort hence resulting in safety. For taking a U-turn the steering wheel needs to be rotated around 3 times lock to lock hence engaging both hands and controlling the vehicle is difficult . Our area of focus is the steering wheel. In most passenger cars, the ratio is between 12:1 and 20:1, whereas for commercial trucks it is 22.4 : 1 to 26.2 : 1 . Current steering systems only provide a fixed steering ratio. Power steering system consists of a component called ECU which takes input like steering torque, angle and vehicle speed and provides output to the motor to rotate the rack and pinion to turn wheels. Our new system will give the driver an option of 2 steering ratios. One steering ratio will be normal which vehicles have and another one will be specially for U-turn, which will fully turn the vehicle in minimum steering wheel rotation. A push to operate system will operate this mechanism and only below a specific speed. Required changes will be made in ECU. A Matlab model of the same is created.*

Keywords—Two steering ratios, ECU, EPS, assist torque, U-turn

1. INTRODUCTION

Taking into consideration electric power steering (EPS) properties, it is way more useful and efficient than the conventional hydraulic steering system (HPS) . EPS system includes an assist motor that directly provides assist torque to the driver. Going further it has the advantages of economy, adjustments are easy , creates less noise and oil pollution and also less waste. . The use of EPS is that it lowers the steering torque that driver has to apply. It does this by providing an assist torque which helps the driver to turn the wheel smoothly and makes to work easy. EPS makes it possible for driver to comfortably handle vehicle without obstruction of hard steering wheel. At all vehicle speeds EPS has turned out to be very helpful. This is because EPS turns off after a certain speed and stops delivering assist torque to rack and pinion, as a result of which at higher speeds vehicle does not change direction easily hence gaining stability. The brain of EPS is a microcontroller called Electronic Control Unit (ECU) . By taking into consideration input from torque sensor and vehicle speed sensor it computes and forwards current signal to assist motor to act accordingly..

Our new system will give the driver an option of 2 steering ratios. One steering ratio will be normal which vehicles have and another one will be specially for U-turn, which will fully turn the vehicles in minimum steering wheel rotation. A push to operate button will be given on the steering wheel, on pressing this button 2nd steering ratio will be activated and upon releasing the button again normal steering ratio will be active. Required changes will be made in ECU to achieve both steering ratio in single system.

This mechanism will be specially useful in mountain passes, steep turns and for truck drivers , since trucks have large steering ratios.

2. STRUCTURE AND WORKING PRINCIPLE OF EPS

A. Structure

The EPS system is principally composed of steering wheel, torque sensor, ECU, BLDCmotor, planetary gear, rack and pinion. The structure diagram of the electric power steering system is shown in figure 1.

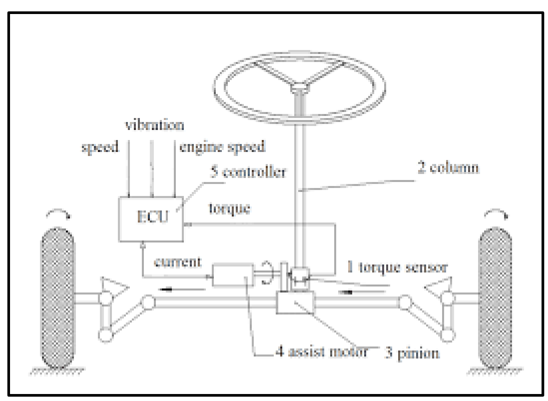

Fig 1: EPS structure

B. Working Principle

Once the driving force turns the wheel, the torque sensor on the steering shaft measures steering torque, and sends it to the ECU, and then, in line with the torque and vehicle speed, the ECU calculates and obtains an optimum current needed for the assist motor. At the same time, the ECU collects the signals real-timely, such as input torque, speed, voltage, current, rotor position of assisting motor, and adjusts the motor current, so as to control the output torque and rotation direction of the assist motor to assist the driver steering in order to gain a better driving experience. Within the whole method of system operating, the fault diagnosing module monitors all elements of the system in real-time. Once a failure is detected, the system disconnects the clutch, and uses pure manual steering, and offers a fault signal that makes sure the driving safety.

C. Electronic Control Unit

An ECU unit is the Brain of the system and is needed to drive the electric motor. It consists of three principal functional blocks:

- The control module.
- The power module.
- The control software.

Fig 2: Electronic control unit

3. THE CONTROL MODULE

- This module consists of a silicon chip that's mounted on a PCB together with peripheral elements.
- The module needs many inputs, e.g., signals from the angle sensors that confirm the precise angular relation of the electrical motor's rotor.
- The temperature is monitored for the Power module, protects against overvoltages and currents an d carries out emergency methods just in case of failure.
- It drives the Power module through its output signals.
- The turn-on/turn-off sequences are obsessed with the speed and force needs of the mechanism.

4. THE POWER MODULE

- This module delivers the power to the three-phase motor (mostly brushless DC). The power switches are driven usually by curved pulse breadth modulation that ends up in a curved signal at the phase outputs of the power module.

A. Control Software

A code to manage the electrical motor will be divided into 2 blocks:

- The basic control for the motor, e.g., by means of space vector management (this generates the mandatory pulse breadth modulation (PWM) for all six electronic transistor switches of the ability module)
- The predominant system code with communication protocols, fail-safe operation and diagnostic functions.
- Additional computing power is needed for sensorless operation since the code must convert the response of superimposed pulses into angular data of the rotor.

B. Steering Ratio

The steering ratio is defined as the angle by which a person rotates the steering to the angle by which a vehicle's front tire rotates. Large and heavy duty vehicles have a high steering ratio, it takes more steering wheel turns for trucks and buses to turn the vehicle. In passenger cars steering steering ratio is low as compared, but still it takes significant turns of steering wheel to take u turn . Sport cars have a very low steering ratio, which is necessary for quick and immediate reactions.

5. HARDWARE PART

A. CALCULATIONS

TABLE-1: Rack

Module	2
Pressure Angle	*20*

Face Width	*10*
Pitch Height	*10*
Length	*356*

Above measurements are in 'mm'

TABLE-2: Pinion

Module	2
Number of Teeth	23
Pressure Angle	20
Face Width	10
Pitch Circle Diameter	46

Above measurements are in 'mm'

TABLE-3: Specifications

Wheel base	1561
Steering ratio	3:1
Rack travel	107.95
Tie rod length	320
Lock to lock turns	2.87
Steering wheel diameter	200

Above measurements are in 'mm'

B. PHOTOS

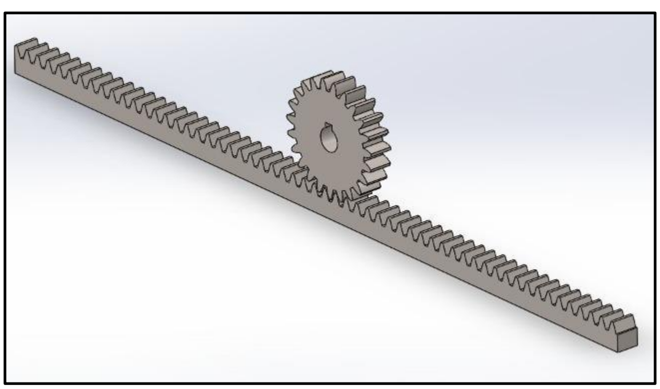

Fig 3: Rack and Pinion assembly

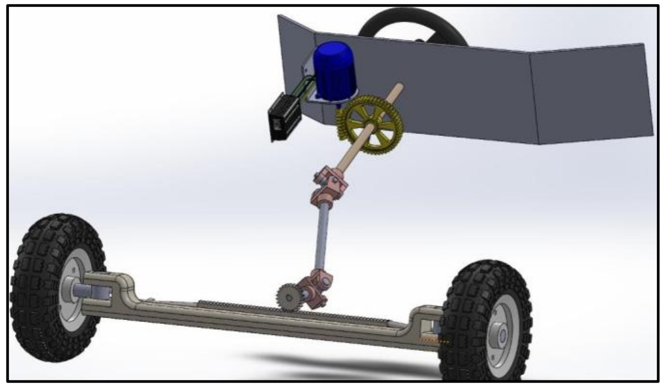

Fig 4: Final assembly

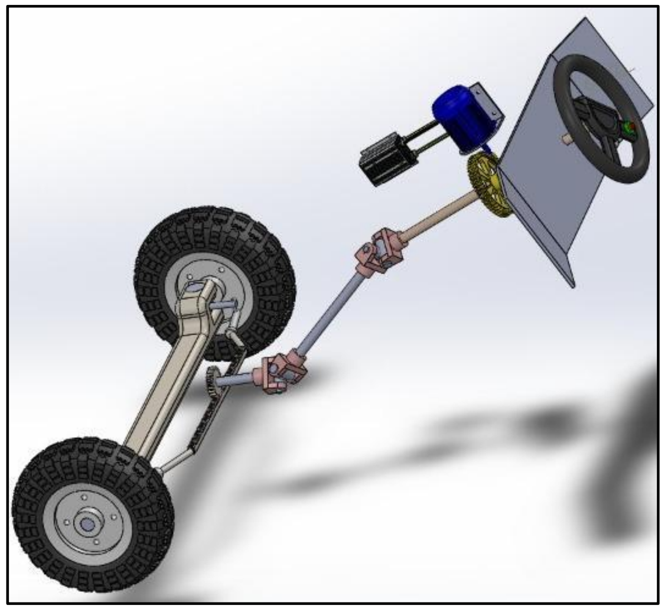

Fig 5: Final assembly

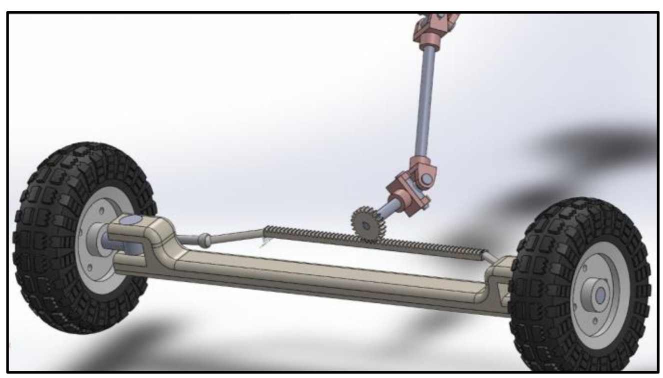

Fig 6: Final assembly

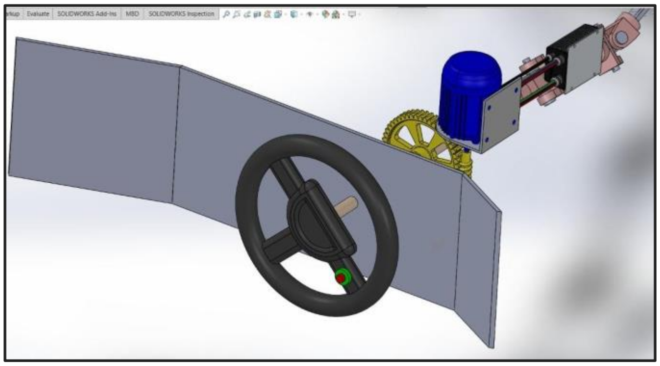

Fig 7: Push to operate button

6. SOFTWARE PART

A. ECU Design

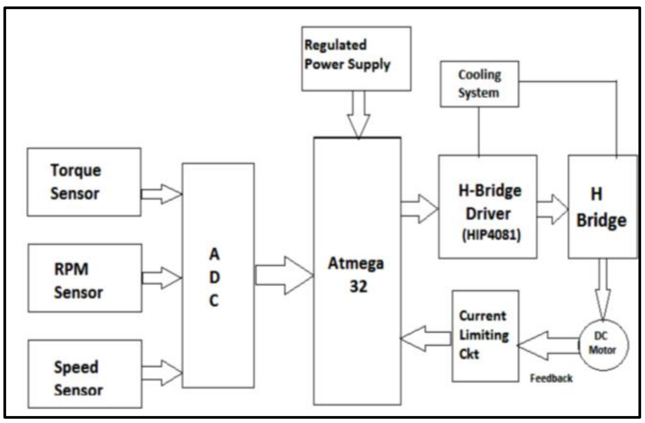

Fig 8: ECU Block Diagram

ADC converts the three analog information that three sensors provide . The data that ADC provides is processed using ATMEGA-32 which is a microcontroller . Following logic is used to drive EPS

- EPS is enabled if the RPM sensor gives high output and disabled if it gives low output
- As soon as vehicle crosses 80Km/hr marks , speed sensor reacts and gives signal to EPS to turn off and henceforward vehicle runs on pure mechanical assisted steering.
- For eg - if the torque sensor gives voltage output as 2.5v in this case PWM (Pulse width modulation) is 0 .
- In case of turning wheels to right or left direction , when output of torque sensor is less than 2.5v vehicle turns left and vice a versa i.e vehicle turns right when output is more than 2.5v

B. Assist Map

For the standardization of ECU globally and for safe driving an assist map is created. In this graph steering torque vs assist torque is plotted. This graph shows amount of torque that should be provided by the motor at respective vehicle speeds. The vehicle speed and assist torque are inversely proportional to each other. This is done to ensure a safe driving experience, hence driver will be able to handle vehicle comfortably even at high speeds. With increase in speed assist motor provides less torque, therefore turning vehicle left or right becomes hard and stability is gained. As vehicle touches and exceeds the mark of 80Km\hr EPS stops working, as a result of which driver needs to deliver more torque hence turning vehicle less. As per the assist map, as soon as the driver torque reaches 2Nm, assist motor starts delivering assist torque to rack and pinion and at the same time assist torque will compensate the steering torque so that person will apply 2Nm torque only to turn the wheel . Above mentioned situation is for speed till 10Km/hr . For further conditions and vehicle speeds, ECU will act according to assist map shown.

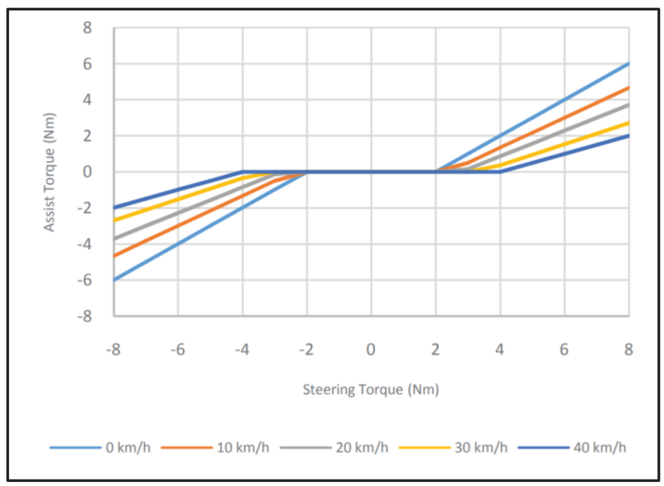

Fig 9: Assist Map

C. ECU Logic

Assist characteristic of electric power steering refers to the relationship between input parameters that are torque and speed, and output parameter that is assist torque or can be said as current of the motor. When vehicle is in motion as vehicle's speed goes on increasing resistance observed in steering wheel decreases, so the assist torque of motor should decrease with the increase of speed, and when the speed exceeds a certain limit, power of motor is cut-off. The three common assist characteristic curves are linear, folding lines and curves type. Out of which the first one that is Linear assist characteristic curves are easy to adjust, simple in form, implement in practice, and used most widely. Linear assist characteristic can be represented as the following function

$$T_h = \begin{cases} 0, & 0 \le T_d < T_{d0} \\ f(v) \cdot (T_d - T_{d0}), & T_{d0} \le T_d < T_{d\,max} \\ f(v) \cdot (T_{d\,max} - T_{d0}), & T_d \ge T_{d\,max} \end{cases}$$

Here Th is the assist torque to be provided by the motor , f(v) is coefficient of speed induction . Th max is the maximum capacity the assist motor can provide., Td0 is the minimum input torque of driver at the beginning of the motor's output power, Tdmax is the input torque of driver at the maximum power of motor. Establishing the characteristic parameters of assist curves as follows Td0=1Nm, Tdmax=7.6Nm, Th max=22Nm. According to the rules speed induction coefficient is considered. No power is given to motor when the speed is more than 80 km/hr.

TABLE-4: Induction coefficient of different speed

Speed (Km/hr)	0	10	20	30	40	60	80
Induction Coefficient	3.16	2.15	1.85	1.50	1.30	1.05	0.72w

D. Methodology

Driver will activate 3:1 steering ratio with a push-to-operate button given on the steering wheel. Power module delivers the power and Control Software operates the assist motor by means of space vector control. This generates the necessary pulse width modulation (PWM) for all six Field-effect transistor FET switches of the power module. Push to operate switch will command 'Control Software' and 'command power module' to supply assist torque 5 times more in order to achieve 3:1 ratio . Hence with the same driver torque wheels will turn 5 times more as compared to normal turning when button is active, resulting in the vehicle making U-turn.

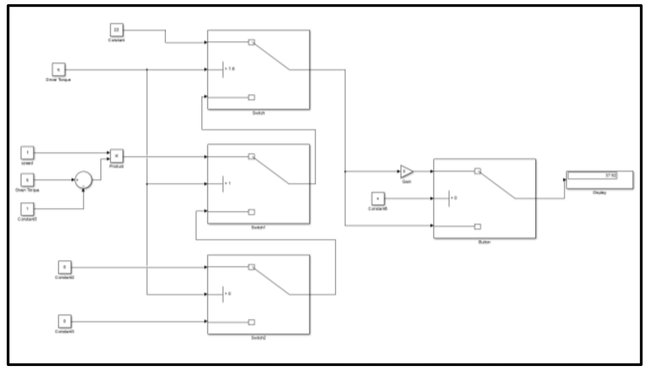

Fig 10: ECU simulink model

7. RESULTS

To prove that when push to operate button is pressed vehicle will take u-turn in just ⅕ th steering torque and ⅕ th steering angle, we have recorded to outputs keeping same torque and vehicle speed in both cases

TABLE-5:

	Normal Steering Ratio	Extra Steering ratio for U turn
value	15:1	3:1
Steering wheel Turns required for U turn	2.5	0.5
Angle covered by steering wheel	900 deg	180 deg

Usually passenger cars have steering ratio 15:1 that means for taking u turn steering wheels needs to be turned 2.5 times i.e 900 deg to either side from idle position. Second steering ratio we are providing to driver is 3:1 which means steering wheel rotates 0.5 turns i.e 180 deg to either side from idle position

In first output Vehicle speed is taken as 35 Km/hr and Torque given by driver is taken as 4 Nm. In second output vehicle speed is kept same i.e 35 Km/hr and torque given by driver is also kept the same i.e 4 Nm ,but in this case push to operate button is pressed hence the second steering ratio (3:1) used for U- turn is activated and results are recorded.

Display shows assist torque which will be provided by motor

a) 15:1 steering ratio

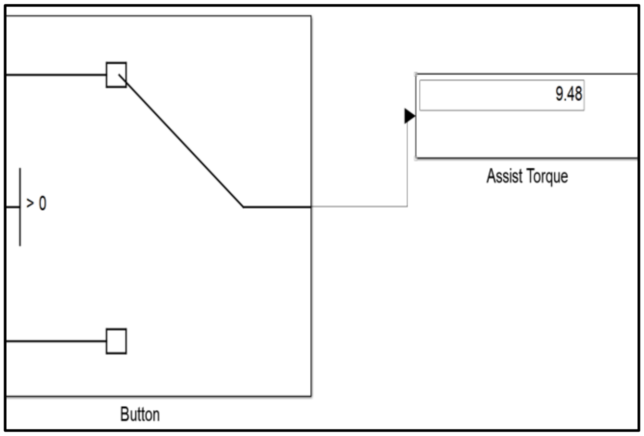

Fig 11: Display showing assist torque (Nm)

```
q = 4
s = 0
y = input('Enter speed '
if 0<y<=10
    f = 3.16
elseif 10<y<=20
    f= 2.15
elseif 20<y<=30
    f= 1.85
elseif 30<y<=40
    f= 1.50
elseif 40<y<=60
    f= 1.3
elseif 60<y<=80
    f= 1.05
else
    f= 0.72
end
```

Fig 12: Push to operate button Off (s)

b) 3:1 steering ratio

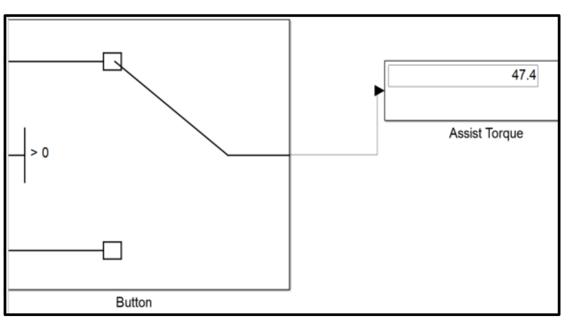

Fig 13: Display showing assist torque (Nm)

```
finalcode.m*
q = 4
s = 1
y = input('Enter speed ')
if 0<y<=10
    f = 3.16
elseif 10<y<=20
    f= 2.15
elseif 20<y<=30
    f= 1.85
elseif 30<y<=40
    f= 1.50
elseif 40<y<=60
    f= 1.3
elseif 60<y<=80
    f= 1.05
else
    f= 0.72
end
Command Window
```

Fig 14: Push to operate button ON (s)

From Fig. 11 , Fig 12, Fig 13, Fig 14 it can be concluded that on activating push to operate button assist motor provides 5 times more torque.

8. ACKNOWLEDGMENT

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