Abstract--- Automated Manual Transmission (AMT) has been the best competitive solution to address the problem of increasing fuel prices and to meet the emission norms. AMT as the name suggests is a manual transmission with clutch and gear actuation done with help of actuators. The basic AMT systems consists of three electro-mechanical linear actuators, one for clutch and two for gear shift and select actuations which are controlled by Transmission control unit (TCU). The main focus of this paper is to present the various low cost design proposal made for AMT.

Key words: AMT, Automated Manual Transmission, Transmission, actuators.

I. INTRODUCTION
The objective of this project is to develop a Low cost AMT system that can be retro fitted on vehicle with existing MT. The developed system should be compact, simple to manufacture, low cost and should have efficiency par with Manual Transmission (MT). AMT is a clutch-less (without clutch pedal) manual transmission system which uses electronic sensors, processors and actuators (hydraulic or electro mechanical) to do clutch actuation and gear shifts as per command of the driver. TCU (Transmission Control Unit) gets the input signals from various sensors like Gear position sensor, Clutch position sensor, brake position sensor, transmission output speed and also Vehicle related signals like torque requirement, engine speed and throttle position from ECU (Engine control unit). The TCU has a control strategy which on receiving the input signals, generates the output signals to clutch actuator and gear shifting actuator. [1]

The actuators to be used for the low cost system are electromechanical actuators. The various considerations and calculations were carried out to finalize the specification for selecting the correct actuators. [2]

II. DESIGN PROPOSALS
Various proposal studies were carried out for designing the AMT system. The basic idea was to develop a simple and low cost system. Care was taken that minimum modifications are required in existing components. Detailed calculations were made before designing the concepts and based on the calculations the required modification were made. The actuators were selected such that they best matched our requirements. The system invited changes in existing gear and clutch cables. Accordingly the new cables were designed. New brackets were designed for clutch actuator and gear actuators. The various proposals which were studied are as follows:

A. Design of rotary electro-mechanical gear actuator
The in-house low cost gear actuator proposal was made by using available resources like wiper motor. The existing wiper motor was selected to design a rotary actuator due to following reasons:

- Availability: wiper motor is readily available as we are going to utilize it from same vehicle for which we are developing the low cost AMT. From the availability point of view, wiper motor is a best option.
- Cost: Cost is also an important factor during the selection of any actuators. In the case of wiper motor it is cheap in all available option.
- Space required: space is a very big constraint in our vehicle. If we use hydraulic actuators there is a problem of space to assemble it in our vehicle. But in case of wiper motor, there is not a big problem. For this we have to some change in our gear console.
- Input voltage: Wiper motor takes the 12 voltage. So it can be used readily.
- Force required: It is a very important parameter during the selection. Wiper motor has sufficient force for shifting the gear in a predefined time. The force requirement can be adjusted with the linkage system designed.
- Speed of actuators: wiper motor has sufficient rpm to execute the gear in predefined time.

Effectiveness: Wiper motor is more effective than hydraulic actuators. Because there are so many losses in hydraulic actuators.

By using wiper motor a rotary actuator was designed. The idea was to use two wiper motor and connect a link to the shaft on which the gear shift and select cables will be connected. If we rotate the shaft of the motor in controlled angle corresponding to stroke required we can achieve desired actuation. This two motor assembly will be fitted on the console area of the vehicle. The detailed assembly can be seen in Fig 1. The assembly consists of two wiper motor, links for connecting cables, bracket to assemble motor and a base plate to mount the entire assembly.

Fig. 1: Rotary gear actuator assembly
The calculations for designing rotary actuator are as follows: Input parameters are taken as follows:
- Total stroke required for gear shift = 44 mm
- Total stroke required for gear select = 30 mm
- Force required for gear shifting = 50 N (actually measured)
Design Proposals for Low Cost Automated Manual Transmission (AMT)  
(IJSRD/Vol. 2/Issue 03/2014/460)

- Force required for rank selection = 50 N (actually measured)
- Link Length = 51 mm
- Linear velocity for Gear Shifting = Stroke required / time = 22/0.45 = 49 mm/sec
- Linear velocity for Rank Selection = Stroke required / time = 14/0.45 = 31 mm/sec
- Motor torque required = Force x link length = 50 * 0.051 = 2.55 Nm
- Angular velocity required for motor = Linear velocity / link length = 50/51 = 0.98 rad/sec
- Speed required for motor = Angular velocity x 60 / (2 x 3.14) = 0.98 * 60 / (2 * 3.14) = 9.3 rpm = 10 rpm

The required motor torque from calculation is above is 2.55 Nm and required motor speed is 10 rpm. This requirement is easily fulfilled by wiper motor as it can give 5 Nm torque at 65 rpm. The rpm motor being Dc motor can be controlled through H bridge circuit for controlled stroke and required rpm. The concept was designed as per design calculation and was analysis was also carried out as shown in Fig 2. Clutch actuation requires very huge force and therefore we cannot use wiper motor for clutch actuation with above mechanism and hence a new mechanism will be required.

The calculation for designing clutch actuator are as follows:
Input parameters are taken as follows:
- Total stroke required for clutch lever = 20 mm
- Force required = 500 N [2]
- Motor shaft diameter = 10 mm
- Arc gear diameter = 50 mm
- Gear ratio = 5
- Radius of rotation for plunger = 45 mm
- Torque at arc gear pivot point = Force at plunger x radius of rotation = 500 * 0.045 = 22.5 Nm
- Torque required for motor = Torque at arc gear pivot point x (motor shaft diameter / Arc gear diameter) = 22.5 * (10 / 50) = 4.5 Nm
- Angular speed for arc gear = linear speed / Arc gear diameter = 60 / 45 = 1.33 rad/sec
- Speed required for arc gear = Angular speed for arc gear x 60 / (2 x 3.14) = 1.33 * 60 / (2 * 3.14) = 13 rpm
- Speed required for motor = Speed required for arc gear x gear ratio = 13 * 5 = 65 rpm

The required motor torque and speed is fulfilled by wiper motor. Hence the proposed mechanism will work smoothly. The retaining spring provides assist to the motor for any additional torque requirement in dynamic conditions.

B. Design of electro-mechanical clutch actuator

An in-house design proposal for clutch actuator was made with the help of wiper motor as shown in Fig. 3. The motor is connected to the arc gear which rotates about Y axis and which has the plunger connected. The plunger moves in X direction and is attached to the clutch lever. The arc gear is connected to retaining spring which helps in actuation on plunger.

The calculations for designing clutch actuator are as follows:
Input parameters are taken as follows:
- Total stroke required for clutch lever = 20 mm
- Force required = 500 N [2]
- Motor shaft diameter = 10 mm
- Arc gear diameter = 50 mm

The packaging study of readily available actuators from some of the suppliers was also carried out. The actuators were selected such that the required specifications were closely matched. The assembly and packaging of bought out actuators is easy as compared to designing a new mechanism with help of available motor. But cost point of view these actuators are expensive when it will come to mass production stage. The basic idea was to package the actuators such that minimum modifications are required in the existing system. The actuators were connected to the respective levers with the help of simple links. The links for gear actuators were only designed to either push or pull a
lever with no mechanical advantage of their own. Two actuators were used for gear shift and select actuation as shown in Fig. 4. Whereas one actuator was used for clutch actuation as shown in Fig. 5. The bought out actuators were selected based on Table 1. \[2\]

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Clutch actuator</th>
<th>Shift actuator</th>
<th>Select actuator</th>
</tr>
</thead>
<tbody>
<tr>
<td>Force</td>
<td>500 N</td>
<td>50 N</td>
<td>50 N</td>
</tr>
<tr>
<td>Liner Speed</td>
<td>60 mm/sec</td>
<td>50 mm/sec</td>
<td>50 mm/sec</td>
</tr>
<tr>
<td>Stroke required</td>
<td>25 mm</td>
<td>44 mm</td>
<td>28 mm</td>
</tr>
<tr>
<td>Type</td>
<td>electro mechanical</td>
<td>electro mechanical</td>
<td>electro mechanical</td>
</tr>
</tbody>
</table>

Table 1: Specification of actuators

The linear actuator for clutch is very difficult to find due to its high force requirements. The actuators matching our specifications are large in size thereby making a packaging issue. Therefore we had to agree on lower specification actuator. This invited the clutch lever to be changed so that we can get the mechanical advantage out of it as shown in Fig 5. The clutch lever also was rotated in order to find the best position for packaging the clutch actuator. The clutch actuator was selected based on following calculations \[2\]

Input parameters for clutch are taken as follows:
- Length of existing Clutch lever = 137 mm = 0.137 m
- Length of extended Clutch lever = 200 mm = 0.200 m
- Length of Clutch Fork= 50 mm = 0.05 m
- Load to disengage Clutch plate= 981 N
- Torque on clutch release shaft for disengagement = Load to disengage clutch plate x Length of Clutch Fork
  = 981 * 0.05 = 49.05 Nm
- Force required at Clutch release lever end = Torque on clutch release shaft for disengagement / Length of clutch release lever
  = 49.05 / 0.200 = 245 N

The clutch actuator link was extended such that it matched the specification of bought out actuator. The existing link was 137 mm and was extended to 200 mm.

III. CONCLUSION

In this paper we have seen the low cost design proposal for AMT system. We have designed the actuators for gear shift and select mechanism with the help of available wiper motor from the vehicle. Also we have designed the actuator for clutch with the help of wiper motor. These in-house designed actuators have advantage on basis of cost factor. But when it comes to duty cycle the wiper motor fails as wiper motor is not designed for constant working as in case of gear shifting were the motor should work frequently when the vehicle is in motion. The proposals with readily available actuators were also done where the actuators best matching our specifications were bought from suppliers. These linear actuators are Dc motor based and provide the easy solution to just retro fit in existing vehicle without any major changes. The actuator selected for clutch however invites linkage to be changed to take mechanical advantage as the actuator fell sort to meet the desired specifications.

After studying these proposal it is concluded that instead of making in-house actuators based on wiper motor it is better to go with the bought out actuators. In house designed actuators will require much time to prove the functionality according to our requirement and would demand increase in the development time of the project. More time means more development cost involved. Also the wiper motor has less duty cycle which is also a problem for functionality. Whereas the bought out actuators are already proven and will save considerable cost of the project. It is easy to make minor changes in the existing vehicle and retro fit the actuators.

IV. FUTURE SCOPE

Further the control of the actuators needs to be understood to make the system optimum. With optimized control strategy the actuators can be controlled so that maximum efficiency is obtained from the system. In order to make the system more efficient actuators exactly matching our specifications should be developed with help of the supplier.
REFERENCES
