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Conceptual Retrofit Design of an IoT Enabled Low-Cost Electric Wheel Chair

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Abstract:- Wheel chairs are essential for people with disability in movement. 44.3% wheel chair users in India drive them manually. Though manual wheel chairs provide good exercise to strengthen muscles, they often tend to cause fatigue and are not suitable for person infected from COVID-19 or suffering from weakness. On the other hand commercially available electric wheel chairs are not affordable. In this paper, the retrofitting of a commercially available manual wheel chair with electrical systems to provide sufficient mobility at low cost and an IOT system to address medical needs of the user is conceptually discussed.

Keywords:- *Wheel Chair, Internet of Things.*

I. INTRODUCTION

With more than 6.1 million people dependent on wheel chairs[1] and 44% of them use manually driven wheel chairs, wheelchairs available in the market are far from self- sufficient . Manual wheel chairs have many advantages in terms of maintenance, ease of handle, transportability and affordability. The manual wheel chair users face a lot of challenges like limited travel distance, fatigue, inaccessibility to some places and longer time of travel. In recent times during the pandemic where users suffer from weakness, manual wheel chair isn't an option. Motorized wheel chairs provide better mobility but they are not easy to handle, have low transportability, high maintenance and are expensive. Costs of these wheelchairs range from 50000 INR to 2,00,000 INR which is 10 fold the manual wheel chair. The aim of the paper is to present a methodology to retrofit manual wheel chair at low cost and convert it to electrical wheel chair with added medical assistance.

From design perspective, Electrical wheel chairs are categorized based on drive, controller and functionality of chassis. Research in design of chassis is aimed at increased accessibility, transportability and dignity of the wheel chair users. Chassis modifications led to design of elevating wheel chair, standing wheel chair, stair climbing wheel chair, and foldable wheel chair. Standing wheel chair gives the user a feel of using their own feet and highly recommended in the use of rehabilitation centers. Foldable wheel chairs are light, occupy less space, easy to handle and are highly transportable. Stair climbing wheel chairs increase accessibility especially in India where stairs are most common. Elevating wheel chairs have found their place in shop floor, super market to enable wheel chair users to reach heights.

The drive system determines stability, comfort, maneuverability and power consumed of the electric wheel chair [2]. The type drive used in the electric wheel chair is determined based on the above factors. Rear wheel drive provides better maneuverability in rough terrain and is not suitable for indoors because of high turning radius. They provide good shock absorption Front wheel drive can climb greater heights and are much suitable for indoors than rear-wheel drive but are tricky to handle and are much suitable for Mid-wheel drive provides better stability and maneuverability and can take 360^{o} turn in tight spaces but cause discomfort over bumps.

Controllers are the human machine interface. Controllers have been designed based on disability of the user, hand joystick, sip and puff, chin joystick, voice control[3] and head control.

Seats provide comfort for users who sit for long durations, they differ in type of cushion foam or gel and are motorized to tilt in space and recline.

During this pandemic, infected users suffer from weaknesses and decrease in oxygen level of blood. Measuring and monitoring the oxygen level of blood helps to respond to the patient in case of emergency there are many pulse oximeters in the market to detect the oxygen level and heart rate. These are expensive and are required to be monitored continuously.

In this paper, a conceptual method to upgrade an existing manual wheel chair to electric wheel chair at affordable price and an IOT architecture to measure pulse and oxygen level of the user and communicate the data to the health care personnel via mobile or website has been discussed.

II. METHODOLOGY

A typical electric wheel chair contains battery and battery management system (BMS), controller and motor. Battery and BMS provide necessary power to drive the motor. A motor converts electrical energy to mechanical energy to move the wheels. Controller helps in maneuvering at the will of the user. In this section, the selection of these components has been discussed.

A. Design and selection of electrical systems

The electrical components include

a) Motor
b) Battery
c) Controller

a) Selection of motor

Motors convert electrical energy to mechanical energy that drives the wheels. There are different motors available Dc motors, synchronous motors, etc with different rating. To select motor to suit our requirements. The power needed to drive wheel chair at certain speed needs to be estimated.

Step1: Estimation of total tractive effort.

For weight of 169kg and maximum speed of 10km/hr the Total tractive effort required to drive wheelchair is summation of rolling resistance($\boldsymbol{F_{rr}}$), hill climbing force($\boldsymbol{F_{hc}}$), acceleration force ($\boldsymbol{F_{la}}$) and aerodynamic force($\boldsymbol{F_{ad}}$)

$$\boldsymbol{TTE} = F_{rr} + F_{ad} + F_{hc} + F_{la}$$

$$\text{TTE} = \mu_{rr} Mg + \frac{\rho A C_d v^2}{2} + mg \sin(\psi) + ma \quad (1)$$

$\mathbf{605.26723N.}$

Step2: Torque required to drive wheel

τ = Torque

R_f = Friction factor that account for frictional losses between bearings, axles etc.

R_{wheel} = radius of drive wheel

From equation 1

$$\boldsymbol{\tau} = R_f * TTE * r_{wheel} \quad (2)$$

3.7829N-m

Step3: Power

τ = Torque from equation (2)

P= 46 W

The lowest available motor is of rating 36V and 250 W. For 250 W motor slippage is

$$S = \frac{Ns - Nr}{Ns}$$

$$S = \frac{290-110}{290} = 0.62068$$

The power required to drive the motor Pin is

$$Pin = \frac{46.07}{(1-0.6208)} = \mathbf{121.474\ W.}$$

Considering efficiency of motor at 144 W it is 85.9% so wattage is

$$\frac{144}{0.859} \sim 170W$$

The selected motor rating is 250 W there are many different types of motors available in the market such as DC motor, 3 phase induction motor, Geared motor, Synchronous motor and Hub motor. Out of all these motors the efficiency of brushless DC motor or hub motor is maximum [4]

b) Selection of battery

The selection of battery mainly depends on

1. Input voltage(V)
2. power consumption (Wattage)
3. Maximum current drain (A)
4. Expected running time by a battery pack

Step 1: Estimation of Battery capacity

It is a measure (typically in Amp-hr) of the charge stored by the battery and is depended on how long you need to run your device (hours), which can be calculated as the follow:

Capacity (Ah) = Device's Wattage (W) x Time to run (Hours) / Battery Voltage (V)

$$= \frac{144}{0.859} \times 3 \div 36$$

= 13.9~15 Ah

Step 2: Estimation of travel distance per charge

Energy stored in battery is voltage x capacity

=15x36

=540 Wh

Energy consumed by motor is 170W

So, the battery life is 3.17 hrs

If the wheel chair travels at the speed of 10km/h the maximum travel distance is 31.7 km.

Step3: Charger rating and charging time estimation

Charger rating is 42V and AH charging time is the maximum energy consumed by battery by charger capacity

$$\frac{36 \times 18}{42 \times 6} = 2.15\ h$$

Quantity	Value
Type	Lithium phosphate($LiPO_4$)
Number of packs	2
Voltage	36 V
Rating per pack	7.5AH
Travel distance per charge	31.7 Km
Charger rating	42V-6AH
Charging time	2.15 H

Table 1 : specifications of battery

c) Selection of Throttle

Most common throttle used is Joystick which is expensive. Since the maximum speed is 10km/hr joystick is underutilized. Instead of it, DPDT switch is chosen to control the movements of the wheelchair. This wheelchair runs on single speed thus there is no need to control speed of the wheel chair. The two DPDT switches are connected and overall architecture of the electrical systems are shown in fig1. The different positions of the DPDT switch enable us to move in different directions as shown in the table 2.

Movement	Position
Forward	AA|
Backward	BB|
Turn	AB/ A|B|

Table2: position of switch and movement of wheel chair.

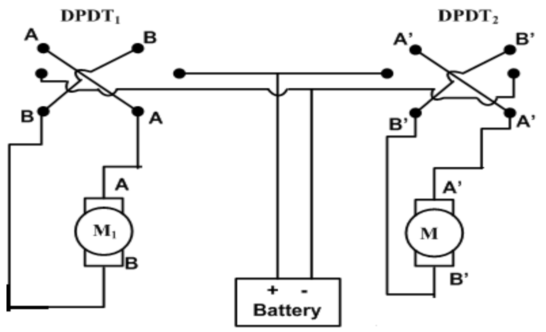

Fig 1- Schematic diagram of the electrical systems

d) Selection of controller.

The electric vehicle controller is the electronics package that operates between the batteries and the motor to control the electric vehicle‘s speed and acceleration. The controller regulates the energy flow from the battery. Many controllers are available in the market based on voltage control, current control [7]. For brushless DC motor, brushless DC controller has to be selected with same rating in voltage and power.

B. Design and analysis of frame to accommodate electrical systems.

The existing wheel axle must accommodate hub motor. The hub motor axle is a 10mm solid rod. Any deformation in wheel axle leads to failure of motor which is not desirable. A structural analysis of the frame is performed using Siemens Nx11.0. In NX a 3D model of the existing wheel chair is generated as shown in fig2

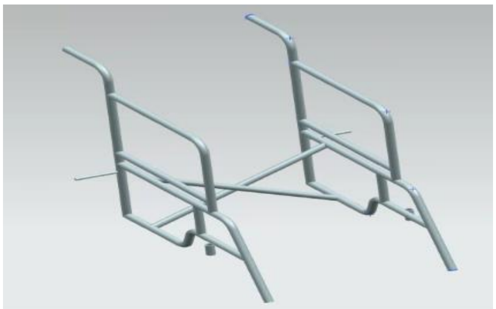
Fig 2: 3D modeling of the existing frame

For analysis, the frame is loaded into NX pre-post application, and the solver Nastran is selected. The material chosen is steel. The element shape for 3D analysis is tetrahedron and size of 3mm. the loading conditions are shown in table:

Parameter	**Condition**
Type of element	tetrahedron
Boundary conditions	Frame legs – fixed
Loading condition	600N on caster wheels 40N weight on arm rests 40 N vertically downwards on wheel axle.

Table 3: Loading conditions for structural analysis

The results obtained in the analysis indicated that there is deformation of approximately 0.5 mm and this deformation may lead to failure of the motor. To reduce this deformation the frame is modified as shown in the fig3:


Fig 3: 3d modeling of modified frame

An analysis with the parameters as described above, results show a deformation of 0.7 and is permissible as shown in fig4. The comparison between the results of the two frames are discussed as shown in table 3.

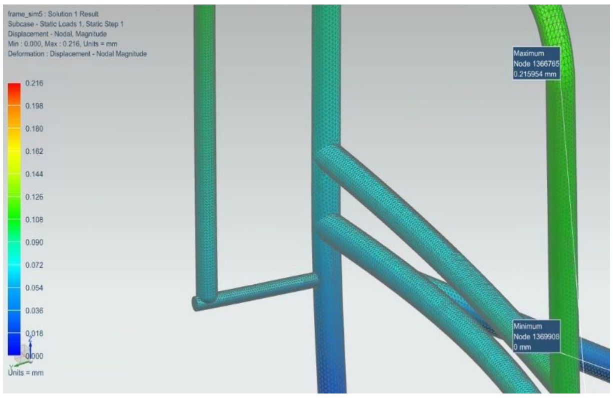
Fig: 4 Analysis of the modified frame

PARAMETER	Before	After
Max deformation	0.404mm	0.072mm
Maximum stress	133.491MPa	5.9 MPa

Table 4: Structural analysis results.

III. IOT ARCHITECTURE

In this pandemic, the corona virus infected people suffer from severe weakness and they require a wheelchair. Oxygen level in blood and pulse rate are the two parameters that are crucial in determining the condition of the user. Drop in oxygen level requires medical attention immediately. The pulse oximeters available in market need someone to monitor the patient continuously. In this section an assistive device is conceptually developed to aid the infected users by collecting information about the pulse and oxygen level and is accessible through web page or by blynk application.

For measuring heart rate and oxygen level in blood MAX30100 pulse oximeter sensor is used. It is an analog sensor which works with 1.8V to 3.3V. It works on the principle that oxygenated blood and deoxygenated blood absorb infrared right differently. Oxygenated blood absorbs infrared light more compared to red light. Whereas deoxygenated blood absorbs red light more than infrared. The photo detector measures the intensity of reflected light at each wavelength and difference is calculated. The heart rate is measured by the intensity of reflected light increases when blood is pumped [5]. The measured pulse is then sent to microcontroller to process the data. There are many microcontrollers in the market such as Arduino, raspberry Pi and Node MCU. Output signal generated by Max30100 cannot be detected by higher level logic controls like Arduino and Raspberry Pi. Node MCU works on 3.3 V is suitable to collect the data and process it. To process the signal, code is written in Arduino IDE 2.0 Beta and loaded into Node MCU. The code is written to enable controller to connect Nodemcu to Blynk as well as the HTML server generated by the network connected. This application can be installed by healthcare professional for continuous monitoring. The sensor architecture is as shown in fig 4.

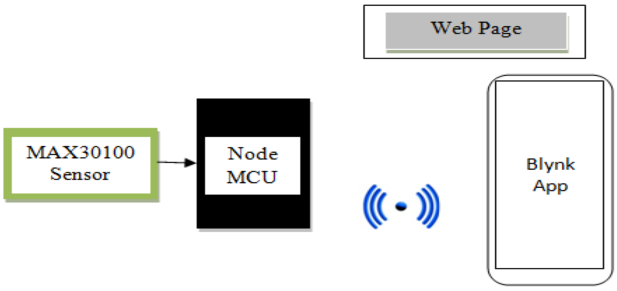

Fig4: IoT architecture

The results obtained can be visualized in serial monitor in testing mode. The I.P address displayed in the serial monitor to which Node MCU is connected when opened in browser as well as Blynk application[6] we can view the reading of the sensor. The results are shown in fig 5 and 6.

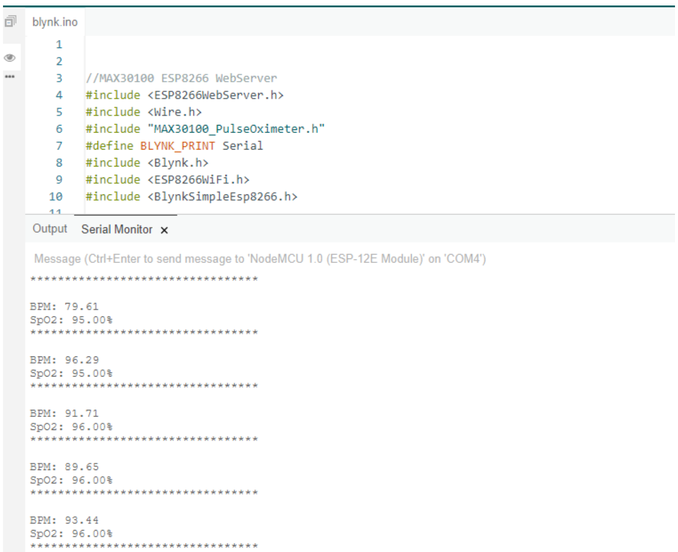

Fig5: Results in serial monitor

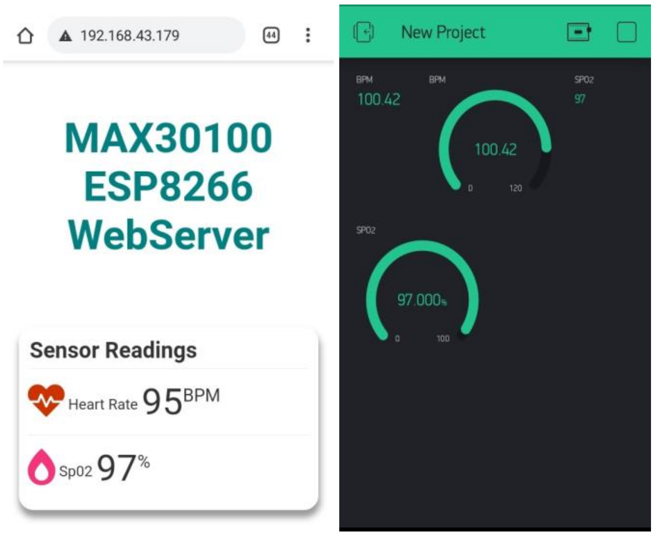

Fig6: a) Results in web page, b) Results in Blynk application.

IV. CONCLUSION

In this paper, A methodology for IoT enabled low cost electric wheel chair is developed by retrofitting manual wheel chair with electrical systems and health monitoring system is conceptually developed and is expected to cost the minimum. This paper discusses the design calculations and guidelines for selecting suitable motor, battery, and controller etc. to run the wheel chair at 10km/h. The same can be extended for 15km/h as well. The IoT architecture displays the heart rate of the user in a webserver as well as in a Blynk app this helps to monitor the patient remotely. The OLED display and alerts can also be added. This design helps greatly to the users affected by COVID 19 and other respiratory problems as well.

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