Electric Vehicle (EV) by Evolt Inc. suitable for a maintenance fleet

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***Abstract*— This paper describes the creation of a pure electric vehicle (EV) after the success achieved with 'REVOLT' over the past decade. Evolt Inc. was incorporated in the State of Delware in the month of June 2018 after our team won the 'Best Consumer Product Award at the CT Business Plan Competition on April 20, 2018 at the Gateway Community College, New Haven, CT. The EV is now suitable for a maintenance fleet with an average speed of 55 mph and distance range of 150 miles.**

The project provided a hands on teaching tool where Digital Controls and all the facets of engineering disciplines within CETA were available under the participation of dedicated graduate students and graduate programs. Last Spring of 2018 a group of Graduate students developed a new PID controller for the EV after it was found that the company which manufactured the Soliton Controller may be out of business. This also provided an impetus for our project and the eventual award has propelled us in this conversion of gas vehicles into the electric vehicle space. Over the past nine years we have successfully created a working model of 'REVOLT'. We now have two world records by NEDRA for a track of quarter mile. We have a new FB account for Evolt Inc:

https://www.facebook.com/ev.shertukde?fref=search

and;

www.hartford.edu/.../club-bios/cetagreen-707.aspx

Please visit for more details to see the present progress.

***Index Terms* — Digital PID Controller, EV, Evolt Inc.**

I. Introduction

With the advent of the alternate energy sources like solar, wind, and ocean etc., several attempts have been made to replace the automobile with Internal Combustion (IC) engine to a pure electric vehicle. This is not a hybrid type of automobile. Many automobile companies like Chevrolet, Nissan and Tesla have working models of their own electric vehicles for normal passenger travel. The 'REVOLT' is an electric vehicle suitable at the moment for drag racing. The students in the electric circuit class were enthusiastic to build a pure electric vehicle with a dc source and a series dc-motor and suitable controller to control the speed of the EV. We chose eight teams with students having different interests to tackle the different sub-systems of the EV. Finally a group of 12 members got together and formed the GREEN 707 Club, primarily driven by student initiative under my guidance as the club's faculty advisor. One of the students donated a 1998 Chevy S-10 truck and a local company Diagnostic Devices Inc. donated $1,000. A campaign then started to raise additional funds and over a time of two years we had raised close to $20,000. The building of the EV started in the Summer of 2010 at a local garage in Bristol, CT. This location was off-campus and students worked in the garage on Friday evenings and Saturday for the next eight months. Slowly but surely the funding from local industry and the Student Government at the University of Hartford increased and we could build a working model of the REVOLT by the end of Fall 2016. In the Spring of 2017 the REVOLT was brought to the National Electric Drag Racing Association (NEDRA) track for its' first run, which was successful in yielding a NEDRA record. The results are shown in the sequel.

II. REVOLT DESIGN

II.1 Motor

We chose the Netgain Warp-11 HV, 400 hp, 288 volts, series dc motor as shown below in Figure 2.1:

Figure 2.1 Chevy S-10, Warp-11 400 hp series dc motor and PID Digital controller.

The EVolt Inc. award received 2018 is shown above the three pictures. Note the significance of the damping coefficient ‘ζ’ and its value of 0.707 that generally yields the optimum control conditions of the motor. The motor is series wound DC that can run at 5,800 rpm with dual water Helwig Carbon red top brushes. The mounting is standard and the shaft in our case is single ended. The insulation class of the motor is ‘H” with fan of high efficiency with a 15 blade. The speed in rpm vs torque in Ft/lbs is shown in Figure 2.2. The motor is manufactured by NetGain Motors, Inc, Lockport, IL [1]

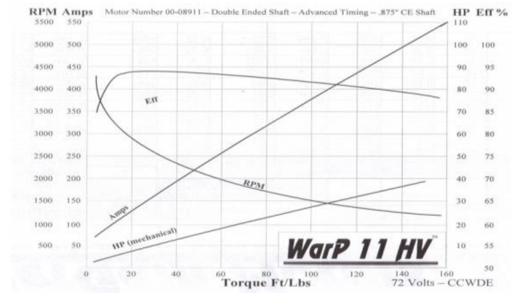


Figure 2.2 Torque vs speed characteristics of Warp 11 motor.

II.2 288 volts, dc Battery pack

Some of the objectives of the Master of Engineering Thesis by Mr. John Paul DiPaola- Tromba [4]; ‘Design of Battery and Charger System for GREEN 707 Electric Drag Vehicle’ were to:

a) Determine present and future technologies available for battery and charging system design

b) Recommend a battery charging system design based on the requirements set forth as a part of the GREEN 707 project

c) Determine a load impact of the charging system on the electric distribution grid

d) Determine a cost estimate for the recommended battery and charging system

Initially we chose the Optima Yellow Top D-51 Battery as a single cell at 12 volts. 24 such batteries were connected in series to form the 288 volts dc power supply. A Yellow Top Optima Battery comparison by Cranking Amp rating is shown in Table 1.1. Since the D-51 battery satisfies the cranking amp rating at 288 volts, we chose this battery to build the complete supply.

Table 1.1 Yellow Top Optima Battery Comparison by Cranking Amp Rating

		ETA	16.0	15.5	15.0	14.5	14.0	13.5	13.0	12.5	12.0
		Power (KW)	130.49	134.70	139.19	143.99	149.14	154.66	160.61	167.03	173.99
System Voltage	# of batteries										
288	24		453.12	467.33	483.32	499.99	517.85	537.03	557.68	579.99	604.16
216	18		604.16	623.64	644.43	666.65	690.46	716.04	743.58	773.32	805.54
144	12		905.23	935.47	966.65	999.98	1035.69	1074.05	1115.36	1159.98	1208.31

A picture of the 288 volts battery system used in REVOLT is shown in Figure 2.3 below

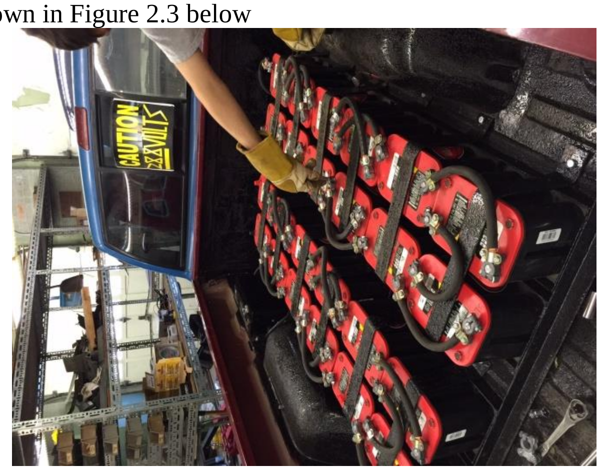
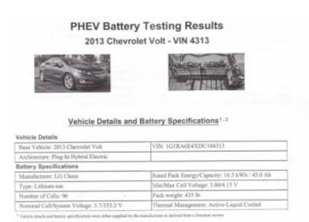


Figure 2.3 288 volt battery pack with Optima batteries D51

As seen from Table 1.1 the Yellow Top D51 met the current demands of the REVOLT. At the first run at the NEDRA track in April of 2017, a few batteries burst open since the instantaneous amperage required at was exceeded the specifications; this led us to go for the PHEV Battery pack as used in Chevrolet volt, manufactured by L G Chem with a rated Pack Energy/Capacity of 16.5 kWh/45.0 Ah. A picture of the new battery cell [3] of the pack is shown in Figure 2.4.



PHEV Battery Testing Results

2013 Chevrolet Volt - VIN 4313

Vehicle Details and Battery Specifications[1,2]

Vehicle Details

Base Vehicle: 2013 Chevrolet Volt	VIN: 1G1RA6E4XDU104313
Architecture: Plug-In Hybrid Electric	

Battery Specifications

Manufacturer: LG Chem	Rated Pack Energy/Capacity: 16.5 kWh / 45.0 Ah
Type: Lithium-ion	Min/Max Cell Voltage: 3.00/4.15 V
Number of Cells: 96	Pack weight: 435 lb
Nominal Cell/System Voltage: 3.7/355.2 V	Thermal Management: Active-Liquid Cooled

Figure 2.4 PHEV Battery pack – 2013 Chevrolet Volt

The min/max cell voltage is 3.00/4.15 volts; with a resulting cell system voltage of 355.2 volts. The pack weight is now reduced to 435 lbs only. Previously the Optima battery pack weighed a total of slightly < 1,000 lbs. This yielded a clear reduction of almost 500 lbs in the total weight of the REVOLT

With this new system the REVOLT is now ready to be tested again at the track in April of 2018. The complete Emergency Services Guidance for Competition Electric Vehicles by NEDRA is available in [5].

II.3 PID Digital Controller

This is a 300 kW dc motor controller manufactured by Evolt Inc. Simsbury, CT [2]. The controller is shown in Figure 2.1. The controller's main contactors with precharge are built-in, integrated heat sink with both liquid and fan cooling. A state of the art film capacitor on the input is rated for twice the ripple current is provided. Also an Ethernet interface streams live performance data while allowing to configure/update the controller with an ordinary web browser. The Soliton's software randomly skips 'pulses' called as dithering to maintain precise control of motor current all the way down to zero amperes. This facilitates no abrupt changes in frequency and no jerkiness at low speeds.

Some of the salient features of the Soliton Controller as follows:

i) Operates at 342 V maximum battery voltage with full current available at 300 Volts.

ii) A continuous current rating of 1000 Amperes over all duty cycles with liquid cooling or 15-20 seconds out of every 90-120 with the suitable fans provided in the assembly.

iii) Brake input – overrides throttle when active for added safety. This property is much needed while drag racing

iv) Throttle controls motor current for a very natural driving with property in (iii) above facilitating the smooth drive.

v) Motor current ramp rate is adjustable at a slow pace of 100 A amperes/second to a tire-boiling 25,000A/s. This is similar to a traction control methodology.

vi) Rugged design based on 600 V 3rd generation industrial IGBT modules.

vii) Thermal derating reduces current at the rate of 2.5%/^{0}C above 55^{0}C

viii) Idle motor speed is between (0, and 500-1500 rpm).

There are two settings: set to zero to disable idle, or set to between 500 and 1500 rpm. Most modern vehicles are set to idle at 600-800 rpm so our Chevy S-10 was set to an idle of 700 rpm as suitable to the IC engine so as to match with the transmission originally used.

ix) PID Loop Parameters are provided set as follows:

P - with a recommended setting of 30. This sets the proportional gain for the loop.

I – recommended initial setting is 20. This sets the integral gain, which attempts to correct the steady state rpm error. Caution should not be raised to a larger value as it may cause instability.

D – Recommended initial setting is 30. This sets the derivative gain, which sets how quickly the loop reacts to abrupt changes in rpm. This can definitely cause instability if this parameter is increased to a larger value abruptly.

A typical wiring diagram of the PID Digital Controller is shown in Figure 2.5.

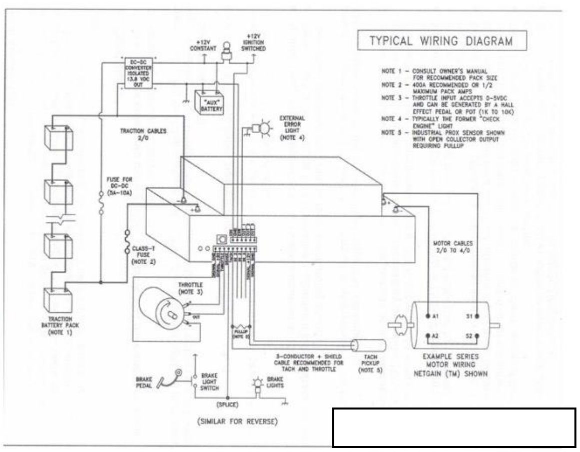


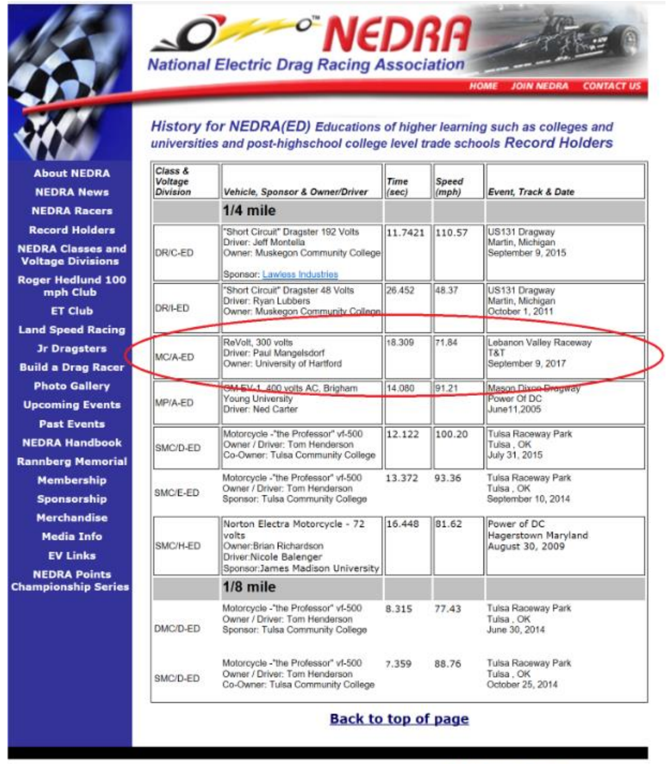
Figure 2.5 Typical Soliton Wiring Diagram to suit Warp-11 Netgain Motor and PID Digital Controller

The under the hood assembly of the Warp 11 HV dc motor, the transmission, Soliton Controller and the other cooling components is shown in Figure 2.6.

Figure 2.6 Under the hood assembly of REVOLT

III. NEDRA Drag Track Results

The first run of REVOLT was held in April of 2017 and the record was cited on September 9, 2017 as shown below from the excerpt from www.NEDRA.org in Figure 2.7



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History for NEDRA(ED) Educations of higher learning such as colleges and universities and post-highschool college level trade schools Record Holders

Class & Voltage Division	Vehicle, Sponsor & Owner/Driver	Time (sec)	Speed (mph)	Event, Track & Date
	1/4 mile			
DR/C-ED	"Short Circuit" Dragster 192 Volts Driver: Jeff Montella Owner: Muskegon Community College Sponsor: Lawless Industries	11.7421	110.57	US131 Dragway Martin, Michigan September 9, 2015
DR/I-ED	"Short Circuit" Dragster 48 Volts Driver: Ryan Lubbers Owner: Muskegon Community College	26.452	48.37	US131 Dragway Martin, Michigan October 1, 2011
MC/A-ED	ReVolt, 300 volts Driver: Paul Mangelsdorf Owner: University of Hartford	18.309	71.84	Lebanon Valley Raceway T&T September 9, 2017
MP/A-ED	GM EV-1, 400 volts AC, Brigham Young University Driver: Ned Carter	14.080	91.21	Mason Dixon Dragway Power Of DC June11,2005
SMC/D-ED	Motorcycle -"the Professor" vf-500 Owner / Driver: Tom Henderson Co-Owner: Tulsa Community College	12.122	100.20	Tulsa Raceway Park Tulsa , OK July 31, 2015
SMC/E-ED	Motorcycle -"the Professor" vf-500 Owner / Driver: Tom Henderson Sponsor: Tulsa Community College	13.372	93.36	Tulsa Raceway Park Tulsa , OK September 10, 2014
SMC/H-ED	Norton Electra Motorcycle - 72 volts Owner:Brian Richardson Driver:Nicole Balenger Sponsor:James Madison University	16.448	81.62	Power of DC Hagerstown Maryland August 30, 2009
	1/8 mile			
DMC/D-ED	Motorcycle -"the Professor" vf-500 Owner / Driver: Tom Henderson Sponsor: Tulsa Community College	8.315	77.43	Tulsa Raceway Park Tulsa , OK June 30, 2014
SMC/D-ED	Motorcycle -"the Professor" vf-500 Owner / Driver: Tom Henderson Co-Owner: Tulsa Community College	7.359	88.76	Tulsa Raceway Park Tulsa , OK October 25, 2014

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Figure 2.7 NEDRA record for REVOLT

IV Conclusions

The next step is to improve the performance of REVOLT with the new PHEV battery pack and a differential in the rear axle. We will be aiming at a speed of 92 mph and try and cover the ¼ mile track in less than 10 seconds. This next run will take place in April of 2018

V Acknowledgements

We acknowledge the support of all the contributing departments at Diagnostic Devices Inc, 50 Wolcott Road, Simsbury, CT 06070.
www.diagnostic-devices.com

References

[1] Warp 11, Application Notes and Service and Support Manual for Warp Motors; Version 2.1, June 30, 2016; Copyright 2014-2015-2018, Netgain Motors Inc.; www.go-ev.com

[2] PID Digital Controller for 300 kW DC Motor Control Owners' Manual; Evolt Inc. Simsbury, CT

[3]PHEV Battery Testing Results, 2013 Chevrolet Volt- VIN 4313, Intertek, July, 2014

[4] John Paul DiPaola-Tromba, 'Design of Battery and Charger System for GREEN 707 Electric Drag Vehicle', Master of Engineering Independent Study Thesis Report, CETA, University of Hartford, CT, May 2012

[5] Michael Dunn, 'Emergency Services Guidance for Competition Electric Vehicles', NEDRA Technical Information Bulletin, 2013.001