

A SYSTEM AND METHOD FOR INCREASING EFFICIENCY OF AN ELECTRIC VEHICLE

FIELD OF THE INVENTION

- 5 [001] The present invention relates to a system for increasing efficiency of an Electric Vehicle. More particularly, it relates to a system and method for increasing ideal efficiency of an electric truck.

BACKGROUND OF THE INVENTION

- 10 [002] In recent years, due to a rise in the environmental pollution in countries such as India and an increasing concern in depletion of petroleum resources in the future and cost factor of the petroleum resources, a reduction the fuel consumption of the vehicle was much needed. Keeping in view of the above, many of the companies internationally and in India, spent a huge amount in Research & Development and filed number of patents
15 relating to a vehicle which can run by means of any source of energy and more specifically by means of electricity.

- [003] One of the types is an electric vehicle, which uses one or more electric motors or traction
20 motors for propulsion. The electric vehicle may be powered through a collector system by electricity from off-vehicle sources, or may be self-contained with a battery, solar panels or an electric generator to convert fuel (petrol, diesel or compressed natural gas) to electricity.

- [004] In the Conventional pure electric vehicles, while emission "free," can't go the distances
25 or provide the power (for any extended length of time) as that of the Internal Combustion Engine Vehicles. The Internal combustion engines hazardously pollute the environment. Further the Hybrid Electric Vehicles used both the characteristics in combination, so the vehicle could go as far and as long as most people would want with emitting lesser pollution. On the highway, when internal combustion engines (I.C.E) would work more efficiently, and where the battery would be depleted very quickly in an electric car, the
30 I.C.E is being used. Whereas for shorter, city driving trips, the electric motor is either

used exclusively, or in such a manner that the I.C.E also runs, at its peak efficiency. Although the existing knowledge and the arrangement relating to the electric vehicle works well, there is a need for a Pure Electric vehicle that has high mileage and efficient battery system to provide energy for longer period.

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[005] Thereby the present invention provides a heavy Electric Vehicle that focusses on the improvement in terms of efficiency of the vehicle, ideal functioning of a motor at its peak efficiency, visualizing the battery temperature and its operating condition and capturing 80% of the energy consumed in acceleration and inclination.

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OBJECTIVE OF THE INVENTION

[006] The primary objective of the present invention is to provide a system and method for improving the efficiency of an electric vehicle working at variable speed and torque limit.

15 [007] Another objective of the present invention is to improve the energy efficiency and mileage of this electric vehicle wherein the regenerative braking (regenerative braking) method is being used to recover a part of the braking energy into electrical energy.

[008] Yet another objective of the present invention is to continuously monitor the battery
20 system to prolong the battery life and health through the pulse width modulation based efficient battery water cooling system that runs continuously around the motor surface.

BRIEF DESCRIPTION OF DRAWINGS

[009] A complete understanding of the present invention may be obtained by reference to the
25 accompanying drawings, when taken in conjunction with the detailed description thereof and in which:

[010] Fig. 1 illustrates the Control Area Network (CAN) communication between various components in the vehicle;

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[011] Fig. 2 illustrates the motor torque and speed curve.

SUMMARY OF THE INVENTION

[012] The present invention discloses an electric vehicle with improved energy efficiency and
5 mileage by using regenerative braking (regenerative braking) method to recover a part of
the braking energy into electrical energy. The pulse width modulation based efficient
battery water cooling system is being used that runs continuously around the motor
surface so as to provide continuous monitoring of the battery to prolong the life and health
of the said battery.

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[013] An electric vehicle of the present invention includes at least one battery for storing electric
energy, at least one motor for generating a driving force from the electric energy of the
battery, a motor control unit to control the operation between the battery and the motor ,
a vehicle control unit that controls all the signals and monitors the state of the components
15 thereon, a transmission control unit that measures the propeller shaft speed and shifts the
gear in the gearbox, a battery management system to monitor the individual cell
temperature in battery while charging or discharging to protect it as a protection layer , a
battery cooling system for controlling and monitoring the individual cell temperature to
optimize the battery temperature according to the change in the state of the said battery.

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DETAILED DESCRIPTION OF INVENTION

[014] The following detailed description is merely exemplary in nature and is not intended to
limit the invention or the application and uses of the invention. The detailed description
of the appended drawings is construed as a description of the currently preferred
25 embodiment of the present invention and does not represent the only form in which the
present invention may be practiced. This is to be understood that the same or equivalent
functions may be accomplished, in any order unless expressly and necessarily limited to
a particular order, by different embodiments that are intended to be encompassed within
the scope of the present invention. Furthermore, there is no intention to be bound by any

expressed or implied theory presented in the preceding technical field, background, brief summary or the following detailed description.

5 [015] Accordingly, those of ordinary skill in the art will recognize that various changes and modifications of the embodiments described herein can be made without departing from the scope of the invention. In addition, descriptions of well-known functions and constructions are omitted for clarity and conciseness.

10 [016] Features that are described and/or illustrated with respect to one embodiment may be used in the same way or in a similar way in one or more other embodiments and/or in combination with or instead of the features of the other embodiments.

15 [017] The terms and words used in the following description and claims are not limited to the bibliographical meanings, but, are merely used to enable a clear and consistent understanding of the invention. Accordingly, it should be apparent to those skilled in the art that the following description of exemplary embodiments of the present invention are provided for illustration purpose only and not for the purpose of limiting the invention.

20 [018] It is to be understood that the singular forms “a,” “an,” and “the” include plural referents unless the context clearly dictates otherwise.

25 [019] It should be emphasized that the term “comprises/comprising” when used in this specification is taken to specify the presence of stated features, integers, steps or components but does not preclude the presence or addition of one or more other features, integers, steps, components or groups thereof.

30 [020] The present invention is applicable not only to a pure electric vehicle but also to a hybrid vehicle. However, an embodiment in which the spirit of the present invention thereof is applied to a hybrid vehicle is obvious from an embodiment described hereinafter, in which the spirit of the present invention is applied to a pure electric vehicle. Therefore, an embodiment in which the spirit of the present invention is applied to a pure electric vehicle is hereinafter described in detail.

[021] The invention described herein is an electric vehicle that may be a truck or any heavy vehicle using electric energy stored in the battery as a power source.

[022] In accordance with the present invention FIG. 1 shows a system for optimizing efficiency of an electric truck. The various components of the system are shown in FIG. 1, which includes a transmission control unit (1), a motor control unit (2), a vehicle control unit (3), a battery management system (4), plurality of batteries (4.1-4.10), and a battery cooling unit (5.1-5.3):

- Vehicle Control Unit (VCU) (3) acts as a switch that controls all the signals and monitors the state of the components. Further whenever there is a fault, VCU (3) communicates it to other components and takes necessary actions. Vehicle Control Unit (VCU) (3) acts as a mediator between two Control Area Network (CAN) busses.
- A Transmission Control Unit (TCU)(1) measures the propeller shaft speed and shifts the gear in the gearbox. It calculates the vehicle speed according to the changes between motor control mode and torque control mode.
- Battery Management System (BMS)(4) is a control unit for the batteries where it monitors the individual cell temperature while charging or discharging to protect it as a protection layer to the batteries. It calculates the Battery voltage and Battery current and further calculates schedule of charge corresponding to voltage and current. It also generates faults emerging the battery.
- Motor Control Unit (MCU)(2) is placed between the battery and the motor. It converts the direct current to alternating current for running of the motor. In the case of regeneration, it acts as a rectifier where it converts alternating current to direct current.
- Battery Cooling System (BCS) (5.1-5.3) is a pulse width modulation based water cooling system. The system is optimized to maintain the temperature of the battery during charging and discharging state to enhance the mileage of the electric vehicle.

- [023] In accordance with the present invention the vehicle control unit (3) may comprise plurality of sensors, further each of the sensors may comprise a plurality of sensor elements, A/D converters for converting outputs of the plurality of sensor elements to digital values, a match checking function for a plurality of A/D-converted values, a filter function, and/or a communication interface. The sensors may include a steering angle sensor for measuring a steering wheel rotational angle, a brake pedal position sensor for measuring a brake pedal step-down amount, and/or an accelerator pedal position sensor for measuring an accelerator pedal step-down amount.
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- 10 [024] The vehicle control unit (3) operates and generates a command value based on driver's demand signals and vehicle status signals from sensors, and/or motor driving nodes each controlling a motor thereby enabling driving, steering and braking a vehicle.
- [025] These command values are generated through the nodes of the Control area Network (CAN)(6) Bus. Each of these nodes may have a failure detecting function and operate such that, when a failure is detected in itself with the failure detecting function, the relevant node does not make any action externally of the relevant node except for notifying that the relevant node is in a failed state. When a failure occurs in any node, the control is switched over to the normal nodes, thereby continuing normal operation as an entire system. Each of the driver's demand detecting sensors may be connected to a communication network, and when a failure of the relevant sensor is detected, it notifies that the relevant sensor is in a failed state.
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- [026] In accordance with the present invention the transmission control unit (1) includes a motor for directly converting electric energy to usable mechanical energy and a transmission connected to the motor without clutch. A motor speed sensor detects motor speed and a wheel speed sensor detects wheel speed. An inverter controls the motor and a control unit controls the inverter in accordance with the motor speed sensor signal and the wheel speed sensor signal. The transmission control unit measures the propeller shaft speed and shifts the gear in the gearbox.
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- [027] In accordance with the present invention the battery management system (4) may comprise a plurality of batteries packs (4.1-4.10) wherein the battery pack further comprises a plurality of battery control units (5.1-5.3) corresponding to the respective batteries packs and communicating with the charger control unit. A switch is provided between each battery and the charger. The battery and charger are connected to each other by a power line, and the charger control unit calculates the charging power of the battery calculated from the battery state transmitted from each battery control unit or the calculated charging power transmitted from the battery control unit.
- 10 [028] Accordingly, the battery may be charged from an external power source and supplies power to the motor when the vehicle is traveling. During charging state it is disconnected from the motor. A battery control unit (5) monitors the input of voltage signal to the battery control unit (4), and activates the charging of battery after the battery control unit is activated.
- 15 [029] In accordance with the present invention the battery cooling system (5) is a pulse width modulation based water cooling system. The system is optimized to maintain the temperature of the battery during charging and discharging state to enhance the mileage of the electric vehicle.
- 20 [030] Accordingly, the battery cooling system may comprise plurality of compressors, plurality of condensers, plurality of condenser fans, plurality of expansion valves, plurality of pumps, plurality of piping, and plurality of piping refrigerated plate heat exchangers.
- 25 [031] Accordingly, on the operation of battery cooling system, the compressor takes the refrigerant gas and compresses it to become a high-temperature and high-pressure gas, and then discharges it to the condenser to exchange heat with the low-temperature inlet air generated by the condenser fan through the condenser to lower the high temperature of the compressed gas. The high-pressure refrigerant gas is condensed into a liquid at a normal temperature and high pressure, and at the same time, the low-temperature air inlet is discharged into a high-temperature air outlet. After the normal temperature and high pressure refrigerant liquid passes through the expansion valve, it is throttled by the
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expansion valve into a low temperature and low pressure liquid into the refrigerating plate heat exchanger, and heat exchange is performed in the plate heat exchanger with water entering the higher temperature at the same time, so that the low temperature and low pressure are the liquid refrigerant that evaporates to a low temperature and low pressure gas, and is finally recirculated by the compressor.

[032] During the operation of the battery cooling system, the water pump works 30 second ahead of time. The high temperature water in the battery cools down after the plate heat exchanger of the unit, re-flows into the battery pack, and circulates to dissipate heat for the battery.

[033] During discharge condition of the battery, the battery cooling system is optimized to maintain the temperature upto 40°C.

[034] During charging due to high current from the fast charger the temperature of the battery increases rapidly. In the present invention the battery cooling system is optimized to maintain the temperature between 35°C to 40°C.

[035] The battery cooling system is optimized and monitored via battery management system and instructs the cooling system control unit to run the cooling system according to the requirement of the system.

[036] A simple electrically driven truck powered only by electrical batteries has the disadvantages that the batteries may become depleted while the truck is far from a battery charging station, and even long-distance travel is not possible.

[037] The advantage in fuel mileage arises from the use of regenerative dynamic braking, which converts kinetic energy of motion into electrical power during at least a portion of braking and returns the energy to the battery. It has been found that braking losses account for somewhere near half of all the frictional losses experienced by a vehicle in an urban transit setting. The recovery of this atleast 60 percent of energy, and returning it to the

batteries for further use, permits to cut-off the need for "secondary" fuel-operated electrical generator.

[038] The motor in the electric truck on running develops counter voltage higher than the battery voltage and inverts the current direction thereby feeding current into the battery, while developing a counter torque that acts as a brake. This phase is called regeneration.

[039] In accordance with the present invention in the electric truck (power source), the electric energy stored in the battery is used as a power source. To improve the electric truck mileage and energy efficiency, the regenerative braking (regenerative braking) method is being used to recover a part of the braking energy into electrical energy. Thereby increasing the mileage of the said Electric Truck.

[040] In accordance with the present invention Table 1 shows various efficiency values at which the motor can work corresponding to its speed and torque values. Further, Fig. 2 illustrates the motor curve with the varying efficiency as signified by the contour lines. The X-axis of the graph depicts the varying speed of the motor in rpm and the Y-axis depicts the torque in N.m.

Table 1

Motor speed (rpm)	Output torque (Nm)	Output power(kw)	System efficiency (%)	Bus voltage (V)	Bus Current (A)	Input power (KW)	Line voltage (V)	Phase current (A)	Motor efficiency (%)	Controller efficiency (%)
200	200.5	4.2	85.80%	576	8.6	4.9	163	52.5	93.63%	91.65%
200	400	8.4	85.87%	576	17	9.8	172	98.8	92.79%	92.54%
200	601	12.6	85.32%	576	25.7	14.7	179	142.2	91.50%	93.24%
200	801.6	16.8	84.04%	576	34.7	19.9	184	185.1	89.98%	93.39%
201	1003.2	21.1	82.84%	575	44.3	25.4	188	228.9	88.99%	93.08%
200	1202.9	25.2	81.18%	575	54.1	31.1	193	274	86.91%	93.41%
200	1403.3	29.5	79.41%	575	64.6	37.1	197	320.9	85.34%	93.06%
200	1603.3	33.6	77.42%	575	75.6	43.4	200	371	83.34%	92.89%
200	1803.6	37.8	75.06%	575	87.6	50.3	204	425	81.00%	92.66%
200	2004.8	42	72.50%	575	101.1	58	207	484.6	78.74%	92.07%
200	2206.1	46.2	69.30%	575	116.4	66.7	210	553	75.51%	91.78%
200	2406.3	50.5	65.44%	574	134.7	77.1	215	632.2	71.46%	91.58%

400	199.1	8.3	90.06%	576	16.1	9.3	227	52.4	94.55%	95.25%
400	399.3	16.7	91.06%	576	32	18.4	239	98.7	94.77%	96.08%
401	599.6	25.2	90.89%	575	48.2	27.7	247	142.1	94.42%	96.26%
400	798.8	33.5	90.24%	575	64.6	37.1	254	185	93.68%	96.32%
400	999.1	41.9	89.48%	575	81.5	46.8	258	228.8	92.91%	96.31%
400	1199	50.3	88.54%	575	98.9	56.8	263	273.7	91.96%	96.29%
400	1397.7	58.5	87.43%	575	116.6	67	268	320.6	91.00%	96.07%
400	1597.6	67	86.19%	575	135.4	77.7	273	370.7	89.80%	95.99%
401	1797.6	75.4	84.75%	574	155.2	89	277	424.7	88.58%	95.67%
400	1997	83.7	82.96%	574	176	100.9	281	484.1	86.88%	95.49%
400	2197.8	92.1	80.75%	574	199.3	114.1	285	552.5	84.94%	95.06%
401	2397.5	100.6	78.87%	574	222.8	127.5	290	631.5	83.30%	94.69%
600	197.8	12.4	91.54%	576	23.6	13.6	277	52.3	94.56%	96.80%
600	397.7	25	92.92%	575	46.8	26.9	290	98.6	95.56%	97.24%
600	597.7	37.6	93.05%	575	70.3	40.4	299	141.8	95.53%	97.41%
600	796.4	50	92.73%	575	93.9	53.9	306	184.7	95.19%	97.41%
600	996.8	62.7	92.27%	575	118.3	67.9	312	228.4	94.75%	97.38%
600	1195.8	75.1	91.63%	575	142.8	82	318	273.2	94.17%	97.30%
600	1394.7	87.7	90.89%	574	168.1	96.5	324	320.1	93.44%	97.27%
600	1593.7	100.2	89.99%	574	194.1	111.3	330	370.1	92.73%	97.04%
600	1793.2	112.7	88.94%	574	221.1	126.7	334	424	91.72%	96.97%
600	1992.4	125.2	87.64%	573	249.5	142.9	338	483.4	90.72%	96.60%
600	2192.7	137.9	86.01%	573	280.2	160.3	343	551.6	89.25%	96.37%
600	2389.7	150.2	83.82%	573	313.9	179.2	350	630.7	87.20%	96.13%
800	196.6	16.5	92.33%	576	31.1	17.8	318	52.3	94.69%	97.50%
800	395.8	33.2	93.90%	575	61.5	35.3	333	98.4	96.02%	97.80%
800	594.7	49.8	94.14%	575	92.1	52.9	344	141.6	96.09%	97.97%
800	793	66.5	93.95%	575	123.2	70.7	352	184.3	95.92%	97.95%
801	992.9	83.3	93.63%	574	154.9	88.9	358	228	95.57%	97.97%
800	1191.2	99.8	93.16%	574	186.8	107.2	365	272.8	95.23%	97.82%
800	1389.2	116.4	92.57%	574	219.4	125.8	372	319.5	94.66%	97.79%
801	1587.8	133.1	91.87%	574	252.9	144.9	378	369.4	94.10%	97.62%
800	1787.3	149.8	91.01%	573	287.6	164.6	383	423.4	93.27%	97.58%
800	1988.5	166.6	89.95%	573	324	185.3	388	483.5	92.32%	97.43%
800	2198.1	184.2	88.50%	572	364.7	208.1	393	555.5	91.04%	97.21%
800	2349	196.9	87.11%	572	397	226	399	615.5	89.90%	96.90%
1000	195.3	20.5	92.80%	576	38.5	22	355	52.2	94.84%	97.85%
1000	393.8	41.2	94.56%	575	76	43.6	371	98.1	96.25%	98.25%
1000	592.1	62	94.92%	575	113.8	65.3	383	141.1	96.51%	98.36%
1000	789.5	82.7	94.86%	575	151.9	87.2	392	183.6	96.45%	98.36%
1000	988.1	103.5	94.63%	574	190.7	109.4	399	227.1	96.23%	98.33%

	1000	1185.7	124.2	94.27%	574	229.8	131.7	407	271.6	96.00%	98.20%
	1000	1383.1	144.9	93.83%	573	269.5	154.4	414	318.2	95.60%	98.15%
	1000	1580.9	165.6	93.26%	573	310.3	177.5	421	367.9	95.13%	98.04%
	1000	1785.6	187.1	92.55%	573	353.6	202.1	426	423.2	94.54%	97.90%
	1001	2005.1	210.1	91.57%	572	401.9	229.4	432	489.4	93.64%	97.78%
	1000	2142.9	224.5	90.76%	572	433.7	247.3	435	536	92.97%	97.63%
	1000	2266.6	237.4	90.09%	571	462.7	263.6	436	584.2	92.28%	97.62%
	1000	2283.9	239.2	89.83%	571	467.6	266.3	437	591	92.13%	97.50%
	1200	193.5	24.3	92.94%	576	45.6	26.2	389	52	94.61%	98.24%
	1201	391.3	49.2	94.95%	575	90.3	51.8	406	97.8	96.38%	98.52%
	1200	589.4	74.1	95.38%	575	135.3	77.7	419	140.8	96.75%	98.58%
	1200	789.6	99.2	95.44%	574	181.3	104	428	183.8	96.80%	98.59%
	1200	992.1	124.7	95.30%	574	228.3	130.8	436	228.1	96.67%	98.58%
	1200	1198.8	150.7	95.02%	573	276.9	158.6	445	274.8	96.49%	98.48%
	1200	1412	177.5	94.60%	573	328.3	187.6	452	325.4	96.12%	98.42%
	1200	1618	203.4	94.06%	572	378.7	216.2	452	378.8	95.65%	98.33%
	1200	1777.6	223.5	93.40%	572	419.4	239.3	451	429	95.11%	98.21%
	1200	1926	242.1	92.39%	571	459.8	262	450	491.1	94.29%	97.99%
	1200	1955.8	245.8	92.02%	571	469	267.1	450	507.9	93.96%	97.93%
	1400	152.7	22.4	91.76%	576	42.5	24.4	416	41.8	94.06%	97.55%
	1401	309.2	45.4	94.44%	575	83.6	48	431	79.3	96.22%	98.15%
	1400	473.9	69.5	95.26%	575	127.1	73	445	115.9	96.82%	98.39%
	1400	642.2	94.2	95.54%	574	172.3	98.6	449	152.5	96.98%	98.51%
	1400	803.9	117.9	95.53%	574	215.8	123.4	448	189.9	97.01%	98.48%
	1400	962.3	141.1	95.33%	573	258.9	148	447	229.3	96.82%	98.47%
	1400	1119.1	164.1	95.01%	573	302.2	172.7	447	271.8	96.61%	98.35%
	1400	1276.5	187.2	94.52%	573	346.8	198	446	319.6	96.29%	98.16%
	1400	1449.6	212.6	93.52%	572	398.4	227.3	443	389.2	95.40%	98.03%
	1400	1527.4	224	92.62%	572	424.5	241.8	442	437.1	94.74%	97.76%
	1600	115.9	19.4	90.14%	576	37.5	21.6	441	32.7	92.21%	97.76%
	1601	233.3	39.1	93.87%	575	72.7	41.7	450	61.7	95.47%	98.32%
	1600	349.5	58.6	94.98%	575	107.7	61.7	450	90	96.45%	98.48%
	1600	465.2	78	95.42%	575	142.9	81.7	449	119.3	96.83%	98.55%
	1601	582.4	97.6	95.53%	574	178.9	102.2	449	149.8	96.94%	98.55%
	1600	700.3	117.4	95.52%	574	215.3	122.9	448	181	96.94%	98.54%
	1600	818.4	137.2	95.36%	574	252	143.8	447	213.8	96.84%	98.47%
	1600	937.3	157.1	95.14%	573	289.2	165.1	447	249	96.64%	98.44%
	1601	1064	178.3	94.73%	573	329.8	188.2	446	290.4	96.36%	98.32%
	1600	1174.1	196.8	94.24%	572	366	208.8	445	332.4	95.92%	98.25%
	1601	1243.1	208.4	93.64%	572	390.1	222.5	443	368.9	95.51%	98.04%
	1600	1287.3	215.7	93.09%	572	406.8	231.7	442	397.8	95.02%	97.97%

1800	103.9	19.6	89.15%	576	38.4	22	451	34.6	91.13%	97.82%
1801	192.8	36.4	93.02%	575	68.3	39.1	451	58.8	94.63%	98.30%
1800	283.5	53.5	94.38%	575	99	56.6	450	84	95.87%	98.45%
1801	378.2	71.3	94.98%	575	131.4	75.1	450	110.4	96.36%	98.56%
1800	476.1	89.8	95.23%	574	165.3	94.3	449	137.9	96.66%	98.5%
1800	576.4	108.7	95.32%	574	200.1	114	448	166.4	96.69%	98.58%
1800	675.3	127.3	95.29%	574	234.7	133.6	448	195.3	96.69%	98.56%
1801	775.1	146.1	95.12%	573	269.7	153.6	447	226.1	96.59%	98.47%
1800	875	165	94.88%	573	304.9	173.9	446	259.5	96.40%	98.42%
1800	978.4	184.5	94.48%	573	342.4	195.3	446	298.7	96.10%	98.31%
1800	1082.4	204.1	93.66%	572	381.9	217.9	443	353.1	95.46%	98.12%
1800	1128.6	212.8	92.96%	572	401.8	228.9	442	390.3	94.88%	97.98%
2000	81.4	17.1	85.91%	576	34.7	19.9	455	48.1	88.40%	97.19%
2001	177.7	37.2	91.96%	575	70.6	40.5	452	71.7	93.70%	98.14%
2000	276.8	58	93.84%	575	107.7	61.8	450	98.6	95.33%	98.44%
2000	375.4	78.6	94.58%	575	145.1	83.1	449	126.5	96.02%	98.50%
2001	476.2	99.8	94.87%	574	183.8	105.2	449	156	96.26%	98.56%
2001	577	120.9	94.96%	574	222.7	127.3	448	186.2	96.36%	98.55%
2000	675.6	141.5	94.87%	573	261.1	149.2	447	218.2	96.31%	98.50%
2001	776.6	162.7	94.68%	573	300.7	171.8	446	253.5	96.16%	98.46%
2000	885.3	185.5	94.23%	573	344.5	196.8	446	297.8	95.80%	98.36%
2000	974.7	204.2	93.35%	572	383.1	218.7	443	353.2	95.13%	98.14%
2201	61.8	14.2	81.12%	576	30.6	17.6	456	65.6	84.23%	96.31%
2200	140.6	32.4	89.87%	575	62.8	36	454	80.6	91.95%	97.74%
2201	219.2	50.5	92.43%	575	95.2	54.7	452	100	94.15%	98.18%
2200	378.7	87.3	94.20%	574	161.7	92.6	449	144.6	95.65%	98.48%
2200	458.9	105.8	94.47%	574	195.6	111.9	448	168.7	95.88%	98.53%
2201	539.4	124.3	94.58%	574	229.8	131.4	448	194	96.02%	98.49%
2200	618.6	142.6	94.54%	573	263.8	150.8	447	220.9	95.97%	98.51%
2200	699.5	161.2	94.36%	573	298.9	170.8	446	251.3	95.81%	98.48%
2200	781.1	180	94.04%	573	334.9	191.4	446	285.9	95.56%	98.40%
2201	860.5	198.3	93.34%	572	372	212.5	443	334.7	95.03%	98.21%
2200	892.1	205.6	92.66%	572	388.7	221.8	442	367.9	94.47%	98.08%
2401	66.8	16.8	79.93%	576	36.6	21	454	87.1	83.08%	96.21%
2400	98.7	24.8	85.22%	575	50.7	29.1	455	90.3	87.85%	97.01%
2401	160.8	40.4	89.79%	575	78.4	45	454	102.7	91.71%	97.91%

[041] From the above table 1 and the efficiency curve illustrated in Fig. 2 it is inferred that at an input torque of 700-1000 N.m. and at a speed range of 800 to 1400 rpm the electric motor attains the maximum efficiency. The efficiency curve is based on the formula:

$$\text{TORQUE} = \text{HP} \times 9550 \div \text{RPM}$$

$$\text{EFFICIENCY } \eta = (0.7457 \times \text{HP} \times \text{load}) \div P_i$$

[042] Here, HP = motor horsepower, load = Output power as a percentage of rated power, and
5 P_i = input power in kW, rpm = Speed

[043] In accordance with the present invention the control units (i.e. Vehicle control unit(VCU),
motor control unit(MCU), Transmission control unit(TCU), Battery management
system(BMS) discussed above are optimized in such a way that they all try to minimize
10 power consumption from the battery with the help of the highly efficient battery cooling
system, thereby increasing the overall efficiency of the electric vehicle.

[044] While this invention has been described in connection with what is presently considered
to be the most practical and preferred embodiment, it is to be understood that the invention
15 is not limited to the disclosed embodiments, but, on the contrary, is intended to cover
various modifications and equivalent arrangements included within the spirit and scope
of the appended claims.