Solar Energy based Hybrid Electric Car: Part 1

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Abstract: This paper presents the designing aspects of solar energy based Hybrid Electric Car (HEC). The research has presented in three parts due to restriction on length of the article. The analysis of the solar power based HEC is presented in part-1, the implementation of the system is described in part-2 and results are carried out with different possible cases are discussed in part-3. By considering the emission of greenhouse gases from the present day cars & the fuels using are limited, the idea of hybrid vehicles had risen. The hybrid electric car which is driven by a 3 phase induction motor powered by using two power sources is designed. By this proposed model, we are making excessive efforts to reduce carbon emission while transport. In present day scenario the world is looking for solar energy as source based electric cars. But solar (Photovoltaic (PV) cells) itself cannot provide sufficient power to the cars for applications of long drive. So, the alternate power source is mandatory. For consideration of economic issues and long drive applications, incorporate battery is integrated to the system with proper controller. So, the system makes hybrid and more reliable. The MPPT (maximum power point tracing) controller is incorporated to the system by using P&O (perturbation and observation) algorithm which can be utilised for PV system to operate at maximum power level. The model used for vector control deign can be obtained by using the space vector modulation technique. The model can be further extended with eletrolyzer and fuel cell systems to operate the car for long drive application.

Keywords: Hybrid Electric Car, Vector Control, Induction Motor, MPPT, Solar Powered Vehicles, Photovoltaic Cells, Modeling of Battery.

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I. Introduction

Global warming is a very serious concern in worldwide with the increasing temperature every year and increasing amount of gases causing global warming like carbon dioxide, sulphur, etc. One of the main sources for these gases are the emissions from vehicles running on conventional fuel such as petrol, diesel etc. As the global awareness on pollution and face of climate change, the researchers are researching into alternative sources of energy [1-2]. Since automobiles are currently a major source of air pollution, governments and major automotive companies are collaborating to provide an effective solution that will result in the reduction of carbon emissions by reducing the consumption of fossil fuel. The best solution to reduce the emission of carbon from vehicles is to develop the electric vehicles [2].

Since the late 19thcentury until recently several electric vehicles have been designed, manufactured and used throughout the world. Some developments are just prototypes, some are just for concept models of cars, and others were just special purpose vehicles. Electric cars with energy sources as lead-acid batteries are developed for locomotion since the end of the 19th century. These batteries were replaced by the NiMH and Li-ion types later, but in terms of the price with energy ratio, till lead acid batteries still rule. Therefore it is common to find lead-acid batteries are used in electric cars.

In the present world, some of hybrid electric cars are having Diesel engines. These cars have a price and environmental disadvantage, as Diesel engines are more expensive as well as causes to increase pollution. Apart from the hybrid vehicles using engines, the hybrid vehicles also deals only with electric motors. In these type of electric vehicles are having only motor as mechanical energy source. Both the alternating current (AC) and direct current (DC) motors are suitable to use in electric vehicles with the help of proper controllers [2-4]. The selection of motor will be depends on many factors like size, cost, performance, power losses in motor, controllers, etc. Both types of motors are used in electric vehicles and have their own advantages and disadvantages. While the AC motor is less expensive and lighter weight for higher power rating, hence the induction motor is most suitable for electric car application with proper controller. For more information, visit avt.inl.gov. These electric motor and their models in presently existing electric vehicles (EEV) are induction motors, brushless DC motor, permanent magnet synchronous motor (PMSM) and switched reluctance motor (SRM). In electric vehicle, the control objective is the torque of the driving machine. The control system is required to be fast responsive and low-ripple in torque. EV requires that the driving electric motor has a wide range of speed regulation.

By considering the AC motors we are reducing the size of the machine and cost of the equipment. The main drawback is the limitation of energy provided by the battery in electric vehicles. The distance traveled by car will be depends on availability of power in the battery. Hence, an alternate charging patch for batteries is investigated in this paper. The photovoltaic cells are most effective solution to charge the batteries even in running condition of the car. The combination of battery and PV system will helps the car to cover the more distance. This type of electric vehicles can be called as HEV.

II. Selection of Components

Generally Electric Vehicles (EVs) or Hybrid Electric Vehicles (HEVs) are having body of the vehicle, Motor, Power supply from batteries, Power converters and controlling equipment. Apart from these, we have to assume the average weight of the passengers which can capable to drive by the vehicle. In this paper, consider the solar panels also for supply the power to batteries as well as motor. Hence we included the weight of the above mentioned equipment while calculating the rating and sizing the devices or components. The body weight of the vehicle we considered from reference [5]. According to the references [5, 6] and by considering the weight of engine, assumed the weight of the body is approximately 1500 Kg. Hence, the calculation of the size and ratings of the components as followed by:

Required Power based on Vehicle Dynamics:

For deciding the required power rating of the motor for proposed hybrid electric vehicle, the vehicle dynamics like rolling resistance, gradient resistance, aerodynamic drag, etc. has to be considered. For illustration procedure 1500 Kg of grass weight is considered for hybrid electric vehicle in this paper. Toyota Fortuner as shown in Fig. 1 is considered in this paper for designating the parameters.
The required force for driving a vehicle is calculated below [5]:

$$F_{total} = F_{rolling} + F_{gradient} + F_{aerodynamic} \tag{1}$$

Where, F_{total} =Total force; $F_{rolling}$ = force due to Rolling Resistance; $F_{gradient}$ = force due to Gradient Resistance; $F_{aerodynamic}$ = force due to aerodynamic drag.

Fig. 1: Toyota Fortuner [6]

A. Rolling Resistance:

Rolling resistance is the resistance offered to the vehicle due to the contact of tires with road. The formula for calculating force due to rolling resistance is given by equation (2):

$$F_{rolling} = C_{rr} \times M \times g \qquad (2)$$

Where, C_{rr}= coefficient of rolling resistance; M= mass in kg; g= acceleration due to gravity= 9.81 m/s^2;

For the application considered, Crr=0.01; M= 1500 kg;

Therefore, $F_{rolling} = 147.15\,\text{N}$

Required power to overcome the rolling resistance of 147.15 N is:

$$P_{rolling} = F_{rolling} \times \frac{V}{3600} = 2.05 \text{ kW}$$

Where, V=velocity in kmph assumed as 50.

B. Gradient Resistance:

Gradient resistance of the vehicle is the resistance offered to the vehicle while climbing a hill or flyover or while travelling in a downward slope. The angle between the ground and slope of the path is represented as α, which is shown in Fig. 2.

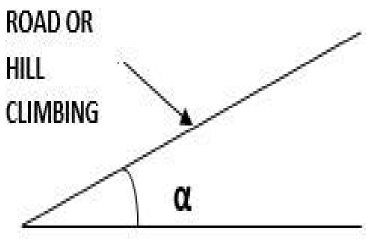

Fig. 2. Angle between the ground and slope of a path

The formula for calculating the gradient resistance is given by equation (3):

$$F_{gradient} = \pm M \times g \times \sin \sim \qquad (3)$$

However, the average angle α =6^0 is considered from reference [7-9]. Hence, the required power to overcome this slope will be

$F_{gradient}$ at 6^0 is = 1538 N.

Power required to overcome the gradient resistance of 1538 N with velocity of 8 kmph is:

$$P_{gradient} = F_{gradient} \times \frac{V}{360} = 3.4 \text{ kW}$$

C. Aerodynamic Drag:

Aerodynamic drag is the resistive force offered due to viscous force acting on the vehicle. It is largely determined by the shape of the vehicle. The formula for calculating the aerodynamic drag is given by equation (4):

$$F_{aerodynami\ c} = 0.5 \times C_A \times A_f \times {}^\circ \times (V + V_0)^2 \qquad (4)$$

These are the three main forces which act on the vehicle when it travels at constant speed. While accelerating and decelerating the effect of force due to inertia also acts. In this illustration, consider the power required to overcome Aerodynamic drag and other resistive forces to be around 1.3 kW.

Therefore, the total power required to move the vehicle is = 2.05 kW + 3.4 kW + 1.3 kW= 6.75 kW. To overcome the problems we selected 7.5 kW rating of motor since 10hp induction motors are widely available.

Selection of Battery:

The major power source in HEVs is battery; hence, the vehicle should run based on availability of energy stored in battery. In this paper, calculated the required power from batteries based on the limited distance. The distance we considered as 150 Km with speed of 50 Kmph which is equals to 3 hours continuous running.

The batteries voltage as taken at 300 V,

Hence ampere hour rating is calculated by below formula:

$$I_{Ah} = \frac{Power \times Time}{Voltage} = \frac{7500 \times 3hr}{300} = 75Ahr$$

The required batteries are available [10] and considered 5 batteries are connected in series with each of 60 V and 100 Ah of rating.

Ratings of PV:

Before deciding the power rating of PV, two major factors are needs to be consider as follows:

A. Charging of the Battery with only PV system: according to solar irradiance, the average time period of the available solar irradiance is 8 hrs. Hence, the battery can able to charge continuously 8 hrs from the PV panels. From battery ratings mentioned above, the battery power-hour is

   $E_{batpower-hour} = 300 \times 75 = 22500$ W-Hour (Which is equals to 3 hrs run time for vehicle)

   $E_{batpower-hour}$ should be matching with PV power generated for 8 hours (i.e., PV energy for 8 hours)

   $E_{PVpower-hour} = P_{PV} \times 8hr$

   Hence, required P_{pv}= 22500/8 = 2812 W

   However, the P_{pv} should be generated from PV panes which are mounted on the surface of the vehicle. So that, the sufficient area should be available on car surface. The available area on car surface is calculated by below section.

B. The availability area on car as below (From Figure 1 and practical measurements):

   1. Side: 39 inches X 175 inches = 47.4 sq. ft

   For two sides: 94.8 sq. ft

   2. Top: 64 inches X 106 inches = 47 sq. ft

   3. Front: 48 inches X 68 inches = 22.6 sq. ft

   4. Back side: 45 inches X 72 inches = 22.5 sq. ft

   Total: 186.9 sq. ft

According to reference [11-12], the available power is 265 W per 17.6 sq. ft.

Hence, available power from available area = 2814 w.

This power is sufficient to charge the battery according to above section. So, the PV system as selected by reference [11-12] and parameters are shown in Table 1. .

Parameters of the PV system [11-12]:

Table 1: Parameters of the PV system

S. NO	PARAMETER	VALUE
1	Open Circuit Voltage (Voc)	63.4 V
2	Short Circuit Current (Isc)	5.89 A
3	Voltage at Maximum Power (Vmpp)	52.4 V
4	Current at Maximum Power (Impp)	5.34 A
5	Number of Modules (Connected In Series)	10

Motor:

Generally DC motors are using in many electric vehicles due to their superior speed-torque characteristics over AC motor. But according to cost, maintenance, size and weight, AC motors are mostly user friendly [2]. Moreover, AC drives are more popular by recent research with advanced controlling techniques with the help of power electronics devices. The BLDC is the best example of AC motor which is widely used in electric vehicles nowadays. However, BLDC is more expensive than induction motor and it also requires hall sensors and permanent magnet. The induction motor can be run as similar to DC shunt motor by vector control, and then similar speed-torque characteristics of DC shunt motor can be achieved. In this project, we considered 3 phase Induction motor to run the hybrid electric vehicle. Motor parameters as shown in Table 2:

Table 2: Induction motor parameters

S. NO	PARAMETER	VALUE
1	Nominal Power	10 HP (7.5 KW)
2	Nominal Voltage (line to line)	400 V
3	Nominal Frequency	50 Hz
4	Stator Resistance (Rs)	0.7384
5	Stator Inductance (Lls)	0.003045
6	Rotor Resistance (Rr’)	0.7402
7	Rotor Inductance (Llr’)	0.003045

8	Mutual Inductance (Lm)	0.1241
9	Inertia (J)	0.0343
10	Pole Pairs	2

III. SYSTEM DESCRIPTION

The general block diagram or layout of the proposed system is shown in Fig. 3. The battery can be charged from either PV system or socket through 1-phase supply as shown in figure. The DC to DC bidirectional converter is used to regulate the charging and discharging of the battery. MPPT is required to extract the maximum power from PV system [1-2, 13-5], in this configuration DC to DC converter is used to work as MPPT of PV system. Hence extra converter is not required for MPPT, it will reduce the system complexity, occupation size and cost. Many algorithms are available to track the maximum power point (MPP) of the PV. Perturb and observe (P and O) algorithm is one of the best methods to achieve the maximum MPP. To reduce the cost and complexity, we integrated the P and O algorithm and controller of the DC to DC bidirectional converter to achieve the both maximum power from PV and regulating the DC link voltage through controlling the charging or discharging of battery current. To improve the life time of the batty [1, 13], considered the state of charge (SOC) while designing the controllers in this paper. Once, if regulated the DC voltage at DC bus or dc link (i.e., input of the inverter), it can be easily achieve the vector control of induction motor. Hence, the speed of the vehicle can be regulated through vector control only. The detailed description of the major system components are divided into below categories:

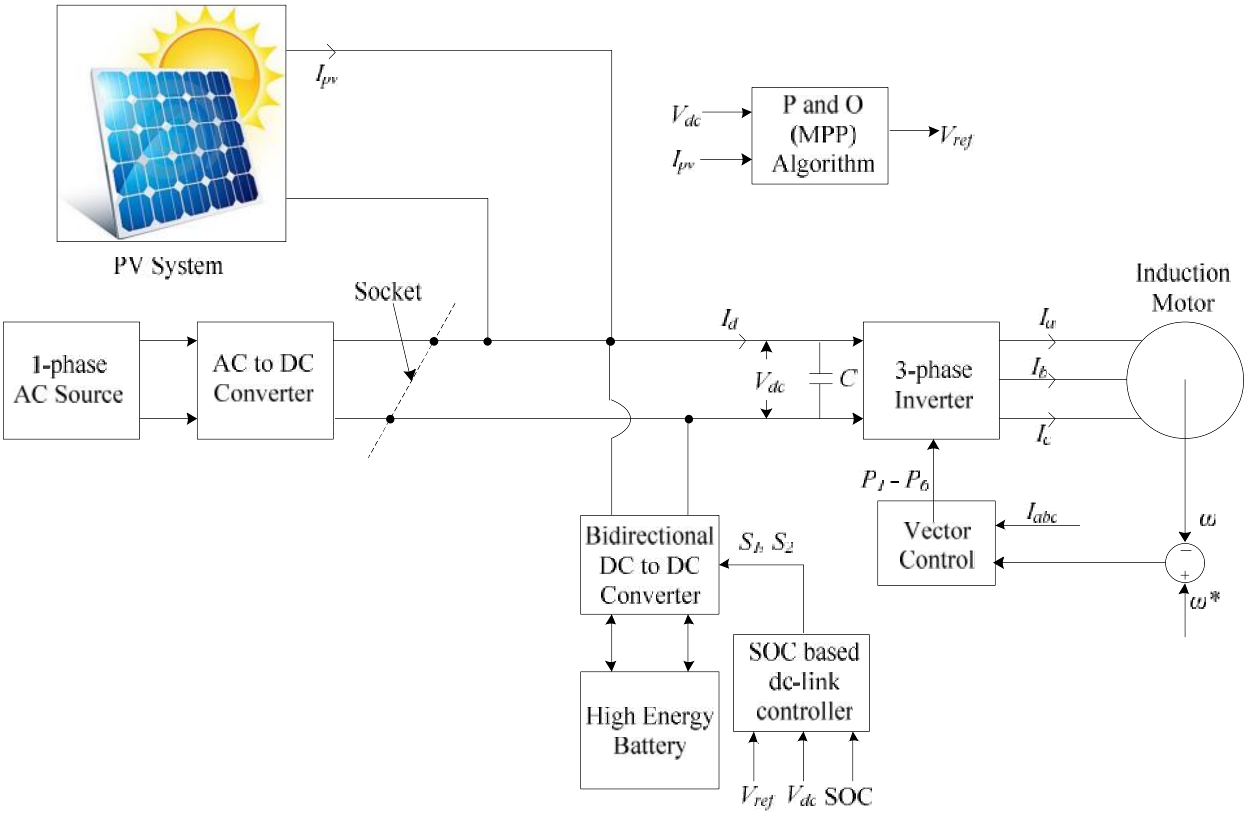

Fig. 3: Proposed System in HEV

Modeling of Photovoltaic (PV) Cell:

A typical photovoltaic system will converter photonic energy to electricity and which consists of solar panels. When the proposed system gets hybridized with PV, the PV model should be shown in Fig. 4. The PV array is described by current-voltage characteristic function as [1-2, 13-17]:

$$I_{PV} = n_p I_{ph} - I_{rs}\left[\exp\left(\frac{q(V_{PV}+I_{PV}R_s)}{AKTn_s}\right)-1\right]-\frac{V_{PV}+I_{PV}R_s}{R_{sh}} \tag{5}$$

Where n_s and n_p are the number of cells connected in series and then in parallel, q=1.602·10^{-19} C is the electron charge, K=1.30806·10^{-23} J/K is Boltzmann's constant, A=2 is the p-n junction's idealistic factor, T is the cell's temperature (K), I_{ph} is the cell's photocurrent (it depends on the solar irradiation and temperature).

$$I_{ph} = Isc\frac{G}{G^*}, \tag{6}$$

I_{rs} It is the cell's reverse saturation current, G is the solar irradiance and V_{PV} is cell voltage. The model diagram of PV cell is shown in Fig. 4.

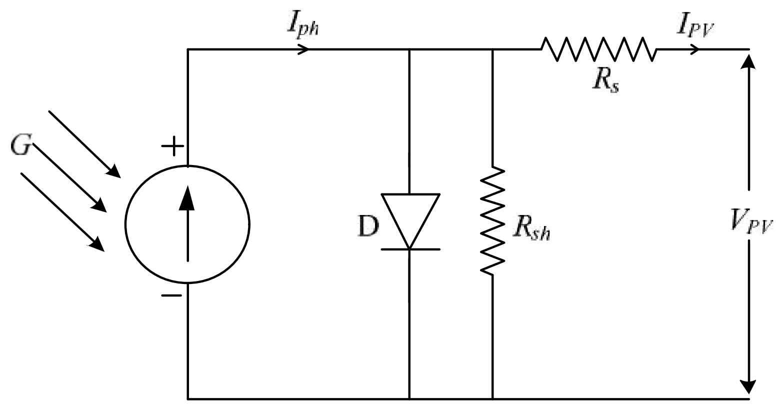

Fig. 4: Schematic Diagram of PV Cell.

Modeling of the Battery:

The battery is an electro-chemical device which consisting of one or more electrochemical cells which can be supply power to electrical devices such as mobiles, TV remotes, electric vehicles, etc. Rechargeable batteries are widely used because it can be discharged and recharged multiple times using an applied electric current. A battery's capacity is measured in the terms of amount of electric charge deliver at the rated voltage. For example, a battery rated at 100 Ah can deliver 5A over a 20 hour period at room temperature.

The battery system is most expensive part of any EV or HEV. It is therefore necessary to control the charging and discharging process to attain its maximal service life. This is the primary task of the battery management system in electric vehicles. The EV or the full HEV battery usually consists of many serially connected elements in order to reach a higher voltage. The same current flows through all elements during the charging. From this point of view it is necessary to balance the voltage on any element to equalize the charge on all cells in the chain, thus extending the battery life. However, individual elements may have the same tolerances but different source resistance. This leads to different voltage on individual elements and their possible damage.

The state of charge (SOC) and the state of health (SOH) of the whole battery is computed from the measured data and stored. In this paper a generic battery model presented in is implemented from [13, 18-21]. For more accurate, temperature parameter also considered while modeling the battery. The modeling is attempted using a simple controlled voltage source with a constant resistance as shown in Fig. 5, where the controlled voltage source is described through below equations.

$$E_m = E_{m0} - K_E(273+\theta)(1-SOC) \quad (7)$$

$$Q_e(t) = Q_{e\_init} + \int_0^t -I_m(\tau)\,d\tau \quad (8)$$

$$I_p = V_{PN} G_{P0} \exp\left(\frac{V_{PN}}{V_{P0}(\tau_P s+1)} + A_P\left(1-\frac{\theta}{\theta_f}\right)\right) \quad (9)$$

$$C(I,\theta) = \frac{K_c C_{0*} K_t}{1+(K_c-1)(I/I^*)^{\delta}},\ K_t = LUT(\theta) \quad (10)$$

Where, $SOC = 1-\frac{Q_e}{C(0,\theta)}$, $DOC = 1-\frac{Q_e}{C(I_{avg},\theta)}$, $\theta(t) = \theta_{init} + \int_0^t \frac{\left(P_s - \frac{(\theta-\theta_a)}{R_\theta}\right)}{C_\theta}d\tau$

where, E_m is the open-circuit voltage (V), E_{m0} is the open circuit voltage at full charge (V), θ is electrolyte temperature (^{0}C), Q_e is the extracted charge (A S), $Q_{e_init}$is the initial extracted charge (A S), I_m is the main branch current (A), τ is an integration time variable, I_P is the current loss in parasitic branch, V_{PN} is the voltage at the parasitic branch, τ_P is a parasitic branch time constant, θ_f is electrolyte freezing temperature (^{0}C), C_{0*} is the no-load capacity at 0^0C, K_t is a temperature dependent look-up table, I^* is a nominal battery current, DOC is a depth of charge, C is the battery capacity (A) , K_E, G_{P0} and δ are constants.

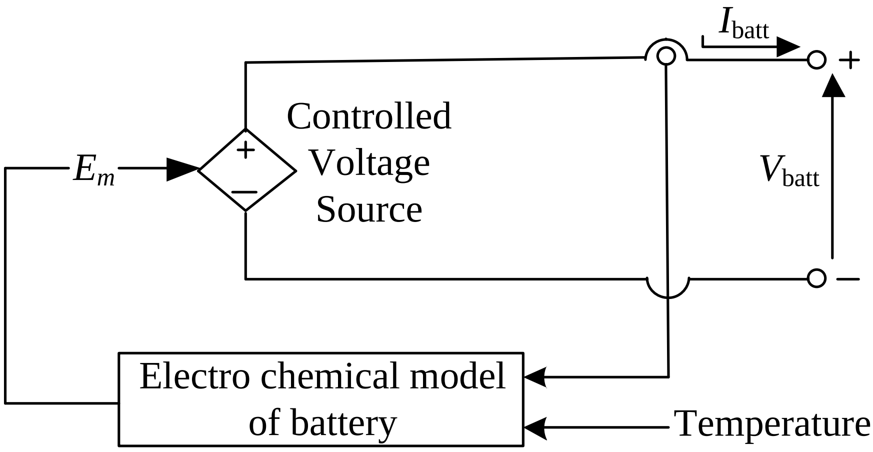

Fig. 5: Generic Battery Model

In Figure 3 a configuration of an HEV is proposed. In this figure it can be seen that the traction motor requires AC input. The main source of electrical power is the PV and Battery which is a DC source. The DC output of the battery is connected to DC to DC bidirectional converter to bucked or boosted according to the requirement of controlling the dc link voltage and then converted into AC using an vector controlled based PWM inverter. The inverter can convert DC to AC with desired voltage magnitude and frequency with proper gating pulses. The output voltage waveforms of PWM based ideal inverters will be considered as sinusoidal with proper LC filters. However, in practically non-sinusoidal and contain certain harmonics will be generated by inverter. The DC to DC converters are implemented from [1-2, 13, 21-23] along with MPPT algorithm [1-2, 13, 22].

Induction Motor Mathematical Model:

The modeling of induction motor carries by following equations with the help of the generalized machine theory, the machine can be models from [3-4, 14-15, 24]

$$\begin{bmatrix} V_{qs} \\ V_{ds} \\ V_{qr} \\ V_{dr} \end{bmatrix} = \begin{bmatrix} R_s + SL_s & \mu_e L_s & SL_m & \mu_e L_m \\ -\mu_e L_s & R_s + SL_s & -\mu_e L_m & SL_m \\ SL_m & (\mu_e - \mu_r)L_m & R_r + SL_r & (\mu_e - \mu_r)L_r \\ -(\mu_e - \mu_r)L_m & SL_m & -(\mu_e - \mu_r)L_r & R_s + SL_r \end{bmatrix} \begin{bmatrix} i_{qs} \\ i_{ds} \\ i_{qr} \\ i_{dr} \end{bmatrix} \tag{11}$$

Where Laplace operator is S. For individually fed machine, for instance a cage motor, $V_{rq} = V_{dr} = 0$.

In case that speed μ_r is aforethought constant (∞ inertia load), the dynamics of electrical machine are insured by a 4th order linear system. Then, inputs V_{sq}, V_{sd} and μ_e , the currents i_{qs}, i_{ds}, i_{qr} and i_{dr} can be derived from abc to dq transformation as already known. If the current source feeds machine, i_{qs}, i_{ds}, i_{qr} and μ_e are independent. Then, the reliant variables V_{sq}, V_{sd}, i_{qr} and i_{dr}, can be obtained from Equation (11).

The electromagnetic torque generated by motor can be expressed as

$$T_e = T_L + J\frac{d\mu_m}{dt} = T_L + \frac{2}{P}J\frac{d\mu_r}{dt} \tag{12}$$

Where T_L = load torque, J = rotor inertia, and μ_m = mechanical speed.

Often, for concise representation, the model of machine and circuits equivalent is asserted in complex form as noted as

$$V_{qs} - jV_{ds} = R_s\left(i_{qs} - ji_{ds}\right) + \frac{d}{dt}\left(\cdot_{qs} - j\cdot_{ds}\right) + j\mu_e\left(\cdot_{qs} - j\cdot_{ds}\right) \tag{13}$$

Or

$$V_{qds} = R_s i_{qds} + \frac{d}{dt}\cdot_{qds} + j\left(\mu_e - \mu_r\right)\cdot_{qds} \tag{14}$$

Where V_{qds}, i_{qds}, etc., are vectors of complex (the superscript has been omitted). Similarly, the equations of rotor can be united to represent

$$V_{qdr} = R_r i_{qdr} + \frac{d}{dt}\cdot_{qdr} + j\left(\mu_e - \mu_r\right)\cdot_{qdr} \tag{15}$$

Let's consider the complex equivalent circuit in frame of rotating where $V_{qdr} = 0$.The above equation tells derivative with respect time by steady state condition and this derivative components substitute to zero. Therefore from Equations (11) - (15), the equations of steady-state can be derived as

$$V_s = R_s I_s + j\mu_e \cdot_s \tag{16}$$

$$0 = \frac{R_s}{S} I_r + J\mu_e \cdot_r \tag{17}$$

From Equations, generally the torque can be represents in the form of vector as

$$T_e = \frac{3}{2}\left(\frac{P}{2}\right)\overline{\cdot_m}\,\overline{I_r}\sin ¢ \tag{18}$$

Resolving the $d^e - q^e$ components variables, torque also can be expressed as

$$T_e = \frac{3}{2}\left(\frac{P}{2}\right)\left(\cdot_{dm} i_{qr} - \cdot_{qm} I_{dr}\right) \tag{19}$$

Derivation of some other torque expressions easily as follows:

$$T_e = \frac{3}{2}\left(\frac{P}{2}\right)\left(\cdot_{dm} i_{qs} - \cdot_{qm} I_{ds}\right) \tag{20}$$

$$T_e = \frac{3}{2}\left(\frac{P}{2}\right)\left(\cdot_{ds} i_{qs} - \cdot_{qs} I_{ds}\right) \tag{21}$$

$$T_e = \frac{3}{2}\left(\frac{P}{2}\right)L_m\left(i_{qs} i_{dr} - i_{ds} i_{qr}\right) \tag{22}$$

$$T_e = \frac{3}{2}\left(\frac{P}{2}\right)\left(\cdot_{dr} i_{qr} - \cdot_{qr} I_{dr}\right) \tag{23}$$

Dynamic Model of Stationary Frame:

The stationary frame of dynamic machine by substituting $\mu_e = 0$ in the above equations, corresponding stationary frame equations are given as

$$V_{qs}^s = R_s i_{qs}^s + \frac{d}{dt}\cdot_{qs}^s \tag{24}$$

$$V_{ds}^s = R_s i_{ds}^s + \frac{d}{dt}\cdot_{ds}^s \tag{25}$$

$$0 = R_r i_{qr}^s + \frac{d}{dt}\cdot_{qr}^s - \mu_r \cdot_{dr}^s \tag{26}$$

$$0 = R_r i_{dr}^s + \frac{d}{dt}\cdot d_{qr}^s + \mu_r \cdot_{qr}^s \tag{27}$$

Where $V_{qr} = V_{dr} = 0$. As cited before, within the stationary frame, the variables appear as sine waves in sinusoidal inputs constant state. The equations of torque (18) - (23) might also be written with the analogous variables in stationary frame as

$$T_e = \frac{3}{2}\left(\frac{P}{2}\right)\left(\cdot_{dm}^s i_{qr}^s - \cdot_{qm}^s i_{dr}^s\right) \tag{28}$$

$$T_e = \frac{3}{2}\left(\frac{P}{2}\right)\left(\cdot_{dm}^s i_{qs}^s - \cdot_{qm}^s i_{ds}^s\right) \tag{29}$$

$$T_e = \frac{3}{2}\left(\frac{P}{2}\right)\left(\cdot_{ds}^s i_{qs}^s - \cdot_{qs}^s i_{ds}^s\right) \tag{30}$$

$$T_e = \frac{3}{2}\left(\frac{P}{2}\right)L_m\left(i_{ds}^s i_{qr}^s - i_{ds}^s i_{qr}^s\right) \tag{31}$$

$$T_e = \frac{3}{2}\left(\frac{P}{2}\right)\left(\cdot\,_{dr}^{s} i_{qr}^s - \cdot\,_{qr}^{s} i_{dr}^s\right) \tag{32}$$

Equations of d-q based voltages also can be noted as

$$V_{qds} = R_s i_{qds}^s + \frac{d}{dt}\cdot\,_{qds}^{s} \tag{33}$$

$$0 = R_r i_{qds}^s + \frac{d}{dt}\cdot\,_{qdr}^{s}\, j\mu_r \cdot\,_{qdr}^{s} \tag{34}$$

$V_{qds}^s = V_{qs}^s - jV_{ds}^s$, $\cdot\,_{qds}^{s} = \cdot\,_{qs}^{s} - j\cdot\,_{ds}^{s}$, $i_{qds}^s = i_{qs}^s - ji_{ds}^s$, $\cdot\,_{qdr}^{s} = \cdot\,_{qr}^{s} - j\cdot\,_{dr}^{s}$ etc., The induction motor can be modeled by using above equations.

IV. CONCLUSION

The presented electric car can operate with both the power sources of batteries and PV system, hence it will be called as hybrid electric car. The analysis and designing of components of hybrid electric car are presented in this paper. Selection of motor, controllers and size is also discussed in details for hybrid electric car. The Toyota model has considered while designing the electrical parameters of the system. The detailed modeling of PV, motor, battery, and power ratings are presented mathematically to validate the system. The detailed implementation of controllers and results are presented in part 2 and part 3 respectively. The overview of the proposed hybrid car is presented in this paper. Apart from results, the detailed mathematical and logical description has provided with reasonable analysis. The battery system is more important in hybrid electric vehicles, hence the temperature parameter also included while modeling the battery since the temperature of the system will vary while running the car.

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