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Vehicle Powertrain Matching and Control Strategy

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Abstract. With the proliferation of electric vehicles within automotive systems, a pronounced intensification has been observed regarding both environmental pollutants and the depletion of energy reserves. Of note to researchers are pure electric vehicles (PEVs); largely because their cost-effectiveness and minimized emissions garner considerable scholarly attention, yet inherent limitations in operational range impede widespread adoption —a phenomenon exemplified by real-world transit data.Under scrutiny in the present inquiry is a PEV platform,upon which emphasis falls: enhancement of overall vehicular performance, blueuction in aggregate energy consumption, as well as augmentation of practical driving distance have been targeted outcomes pursued through a methodological fine-tuning directed at powertrain parameters together with regenerative braking logics. Commencement of the initial parameterization procedures, mediated through vehicle dynamics modeling methodologies, is thus undertaken as a foundational act. These configurations—processed within CRUISE simulation frameworks by way of mutual contrast—subsequently encounter optimization wherein reducer ratios are recalculated through algorithmic modalities exemplified by NSGA-multi-objective constructs. Evidenced in what follows is the crafting of an intricate regulatory schema, one predicated upon fuzzy-logic architectures for regenerative braking, to which limitations endemic to classical fuzzification paradigms lend particularity. Notwithstanding such intrinsic drawbacks, incorporation ensues of an adaptive neuro-fuzzy inference system (ANFIS),designed so that dimensional gaps present within conventional logics might be mitigated. Under subjection to methodical experimental simulations, the strategies articulated above find themselves tested within environments reflecting the Simulink–CRUISE co-simulation ensemble; exposure here occurs under normalized proscribed NEDC and CLTC-P cycles,alongside conditions replicating authentic phenomenological driving scenarios. From these multivalent encounters, validity and operational robustness corresponding to each strategic layer can be discerned in context-dependent evaluative terms.

Keywords: Battery Electric Vehicle (BEV), Powertrain Parameter Matching, NSGA- II Algorithm

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1. Introduction

Perceptible indeed has become the augmentation in proprietorship of standard automotive forms—an observation derivable from emergent employments manifesting discernibly—which upon energy economies and environmental balances exerts considerable strain [1]. Established thereby has been,within the broader transnational automobility sphere,a momentum gravitating toward alternative-energy formulations: an insistent realignment whose contours successive analysis substantiates. To China's "863 Program" thus was attributed prominent status,under which the domain relevant to new-energy vehicle (NEV) innovation—demonstrating previously unseen rapidity both in market absorption and aggregate sales measures—commenced passage through iterative developmental phases distinguished by deliberate intensification trajectories [2].

Within officially promulgated industrial schematics one finds explicitly articulated benchmarks; these so sequenced as to render systematic completion feasible throughout identified temporal partitions,wherein the progression not merely of technical sophistication but of coherent low-carbon systemization remains sponsored institutionally [3]. Not irrelevant is it that apprehension among technological interlocutors reveals a mounting inclination for exclusive electric vehicular architecture—a movement many contemporary analysts construe as emblematic evolutionary orientation in automobility invention history.

Persistently encounteblue are,nonetheless,impediments relative to holistic mass acquirability,exemplified in lacunae pervading extant communal recharge installations and in restrictions embedded within prevailing electricity storage modules or drive machinery coordination schema. Seen from such manifestations,substantial unresolved issues emerge at the interface of infrastructural provision and technologic efficiency,delimiting at present the full operationalization of NEVs on societal scale [4].

2. Basic assumptions

The principal subject examined within this discourse concerns the advancement of both energetic output and financial viability pertaining to electric vehicles; delimited strictly to consideration afforded their longitudinally directed vehicular motion. Central to processes involving powertrain configuration,it is fulfillment achieved by performance indices requiblue of such vehicles upon which focus must necessarily rest,with analysis dealing in dynamical behaviors along the lengthwise axis forming the underlying theoretical substratum whereby parameters are appropriated judiciously to match system requirements. Disclosed from instances derived in relevant studies,the necessity for exhaustive inquiry into these motions becomes apparent [5]. It is by reference to these investigative subtleties that the governing equilibrium formalizations—according to which a road-bound vehicle's movement operates—are articulated as follows:

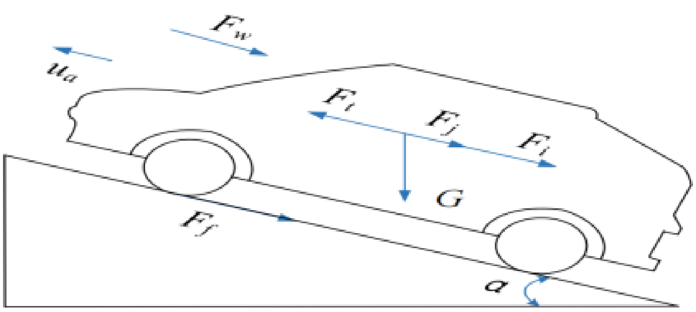

Figure 1. Force diagram of car climbing a hill

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$$F_t = F_f + F_w + F_j + F_i \tag{1}$$

$$F_f = Gfcos\alpha \tag{2}$$

$$F_w = \frac{C_D A {u_a}^2}{21.15} \tag{3}$$

$$F_i = Gsin\alpha \tag{4}$$

$$F_i = G\alpha \tag{5}$$

$$F_j = \delta m \frac{du}{dt} \tag{6}$$

$$F(t) = \frac{T_{tq} i_g i_o \eta_t}{r} \tag{7}$$

$$\frac{T_{tq} i_g i_o \eta_t}{r} = Gfcos\alpha + \frac{C_D A u_a^2}{21.15} + Gsin\alpha + \delta m \frac{du}{dt} \tag{8}$$

Table 1. Basic parameters of target model

essential parameter	numerical value
vehicle overall dimensions(mm)	4745/1790/1550
curb weight (kg)	1650
full load mass(kg)	2033
front face area (m2)	2.3
coefficient of drag	0.31
wheel rolling radius(m)	0.32
wheel base(m)	2.7
distance from center of gravity to front axle(m)	1.42
transmission efficiency	0.96
height of C.G. (m)	0.5
coefficient of rolling resistance	0.008

Table 2. Key performance indicators of target vehicle models

design index	reference value
0~50 km/h acceleration time(s)	<4.5
50~80 km/h acceleration time(s)	<4
maximum speed (km/h)	≥140
maximum gradability (%)	≥25
Range at 60 km/h constant speed(km)	≥400
CLTC-P Cycle Range(km)	≥300

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power matching of drive motor

$$P_1 = \frac{1}{3600\eta_t}\left(mgfv_{max} + \frac{C_D A v_{max}^3}{21.15}\right) \tag{9}$$

$$n_e = \frac{n_{max}}{\beta} \tag{10}$$

With a rise observed in the given parameter,an increase manifests in the torque output of the motor under conditions of reduced rotational speed,attributing to vehicle power performativity an evident elevation. Attributable to excessiveness in this variable,an augmentation emerges in loss phenomena characteristic of the motor architecture. The value,customarily lying within the span demarcated as 2 through 3 by prevalent standardizations, is supported by extant computational data. Demonstrated from such instances,an efficacy-optimized interval for n_e occurs between 2250 and 4500 r/min; the current investigational endeavor thereby selects n_e=3500 r/min as its operative setting.

$$T_e = \frac{9550P_e}{n_e} \tag{11}$$

$$T_{emax} = \lambda T_e \tag{12}$$

The calculated values show that T_{emax} is 245.57Nm and T_e is 122.78 Nm.

3. Modeling and simulation

Commencement of vehicular simulation within the framework of CRUISE software entails,initially,the instantiation of a project entity. Into this digital workspace,modules representative of discrete vehicular constituents are introduced through structural graphical manipulation,with these module units subsequently residing as elemental blocks in the schematic architecture delineated by the user. Physical and communicative linkages among said modules are instituted in subsequent procedural stages—observable here is a deliberate orchestration aligning component interoperability requisite for simulation integrity.Within parametric entry phases,it can be identified that powertrain configuration outcomes,previously deduced via separate engineering calculation or labbench examination processes,find precise transcription into relevant parameter fields belonging to individual modules embedded in the simulation environment. Research practitioners,upon achieving preliminary model completeness,proceed to append algorithmic tasks specifically tailored to investigate dynamic behaviors; notable here is the meticulous specification of operational configurations assigned in preparation for run-time execution. Finally,instances abound where resultant data streams are directed toward curated storage directories—a practice facilitating posterior analysis pblueicated on those simulated vehicular phenomena arising within prescribed temporal boundaries.

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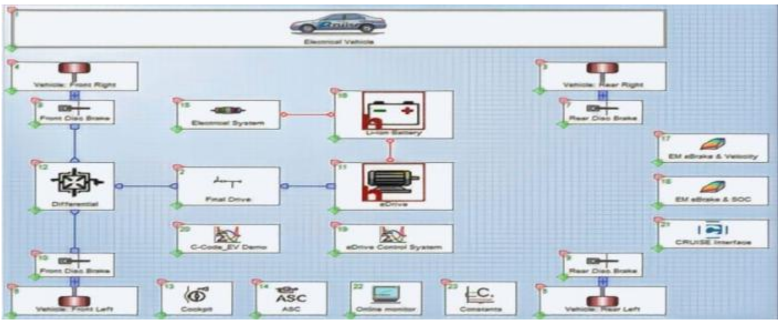

Figure 2. Vehicle dynamic simulation model

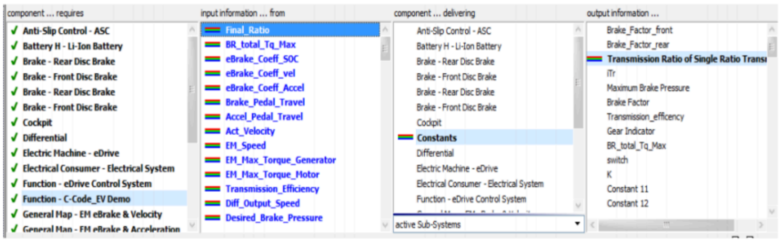

Figure 3. Signal connections of the vehicle

Discernible from the data yielded by simulation,attainment of the designated upper velocity threshold—which has been set at 140 km/h—may be confirmed. In correspondence with this,apparent alignment between variables measured during acceleration intervals and their respective theoretical projections emerges,with documented temporal spans exhibiting adherence to the regulatory constraint by remaining within the limit of 4.5 seconds specified for such phases. Within these outcomes,consistency in operational performance relative to established standards is implied.

4. Study on the control strategy of regenerative braking in automobile

moment balance equati

$$F_{zf}L = Gb + m\frac{du}{dt}h_g \tag{13}$$

$$F_{zr}L = Ga - m\frac{du}{dt}h_g \tag{14}$$

ideal braking force distribution principle

$$F_{bf} + F_{br} = \varphi G \tag{15}$$

$$F_{bf} = \varphi F_{zf} \tag{16}$$

$$F_{br} = \varphi F_{zr} \tag{17}$$

Brake energy recovery,incorporated as an indispensable constituent within the architecture of electric automobility systems,achieves significant prominence in relation to the optimization of

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vehicular kinetic recoupment observable amidst deceleration phases. Substantive archievments have been registeblue under conditions where recuperation of otherwise dissipated momentum is intensified: from this emerges a discernible prolongation of operating trajectory on single charge cycles. Manifested in quantifiable data are extensions feasible for travel span,from which may be inferred the enhanced pragmatic value assigned to contemporary electrified conveyances—value grounded chiefly in attrition mitigation that denotes operational superiority over non-recovering configurations. In exampling empirical surveys,efficacy accrual does not merely pertain to abstract advantage but,rather,assumes relevance concomitant with everyday applications imposed by user requirements and infrastructural variability; it stands evident,thus,that brake energy reclamation enacts a pivotal role,interlacing technical incrementality with functional endurance across modern e-mobility praxis.

5. Conclusion

Central to the disquisition undertaken regarding a nascent exemplar of pure electric vehicle typology,an evaluative orientation emerges towards two principal multidimensional axes—the refinement process concerning the selection and calibration of powertrain parameters on the one hand,and,in another sphere,the orchestration subtleties embodied within regenerative braking governance frameworks. Embedded within such exploratory contours,manifest themselves intentions which converge upon the progressive elevation of holistic vehicular performativity indices,together with the alleviatory addressal of operative distance apprehensions that have become emblematic within electrified mobility discourses. Perceptible from a stratified methodological concatenation is,at the outset,the synthetic engagement with extant intellectual productions both of indigenous and cosmopolitan provenance—a procedural assimilation through which the rudiments constitutive of subsequent investigational architecture are derivatively delineated.

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