Solar Agri-Terrain Vehicle with Intelligent Charging Mechanism Based on Regression Algorithm

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***Abstract*— Several issues on charging algorithm efficiency could be gleaned on especially in the electric vehicle application and absorption capabilities of storage medium used to store solar energy. This paper proposed to develop a model in predicting state of charging switching mechanism based on Multiple Regression Algorithm. The switching mode proposed by this paper embedded two important charging techniques, which performed hybrid charging based on the predicted state of charge of the battery, thus providing efficient, safe and optimized system.**

***Index Terms*— Data Mining, Multiple Regression Analysis, Prediction, Solar PV**

I. Introduction

Current issues in the performance of electric vehicles with solar panels would cover stability and spontaneity of sunlight that is a factor in charging the on board batteries. Solar charge controllers are utilized based on charging algorithm and absorption capabilities of storage medium.

Various solar charge controllers are applied either for fast charging or charging based on battery condition then self-adjust its charging to prolong battery life cycle. This paper proposed to develop a model in predicting state of charging mechanism based on Multiple Regression Algorithm. Factors such as amount of sunlight, current drawn and voltage were considered as triggers in the ability to efficiently charge storage batteries and in line with the type of charging algorithm to be used either Pulse Width Modulation (PWM) or Maximum Power Point Tracking (MPPT) techniques. Thus, provides better way of choosing appropriate algorithm for optimized charging in a given state of charge of the batteries.

In the paper of Abuella [1] on Multiple Linear Regression analysis to generate probabilistic forecasts of solar energy, the authors argued that model's performance would be better for near forecasting horizon than farther horizon, but this is affected by cloudy hours, thereby the entire performance of the model. This would indicate that regression model could be a good basis in this paper aim on forecasting and switching to efficiently apply charging from the PV system to the storage batteries.

Sunlight that translate to energy could be harvested by the Photovoltaic (PV) cells attached on top of the electric or autonomous vehicle, may lead to erratic and inefficient charging. The researcher devised a mechanism that would efficiently decide the charging method to employ based on the amount of sunlight and the current state of charge. The main goal of this paper is to develop a regression model incorporating the attributes into the equation, and utilizing such model using the actual data to efficiently employ appropriate charging algorithm in the system for any state of sunlight that maybe efficiently applied to agri-terrain vehicle. Part of the main goal is to develop the switching algorithm on various modes of charging mechanisms.

II. RELATED STUDIES

This paper was anchored on the work of De Castro et al. [2] in the development of an advanced warning system based on prediction algorithm, which was devised by the researcher relative to the increasing water level and speed. These two factors were considered as triggers to the flashflood, thus become components of the prediction model based on multiple regression function. Osborne [3] made use of the regression equation to forecast unknown variables using input values for the independent variables, which the researcher also based this computation on such approach.

On the other hand, a paper on regression forecasting of solar energy [1] was also the basis in the employment of multiple regression algorithm (MRA) in the prediction of solar energy. Related to this, in this paper MRA was used in deciding between two known algorithms on PWM and MPPT based on the actual state of charging.

For this paper, the prediction model shall be computed and the actual data will be the input to the regression equation. Two attributes were entered into the equations and these are the amount of sunlight directed towards the solar panels and the current drawn from the PV panels. The model equation will be the basis in deciding on the algorithm switching between MPPT and PWM.

A. Pulse Width Modulation (PWM) Algorithm

Several controllers are now available in the market such

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as Pulse Width Modulation (PWM), which is one of the most effective means to reach constant voltage battery charging by switching the solar system controller's power devices [4]. When in PWM regulation, the current from the solar array tapers according to the battery's condition and recharging needs. This way the battery is protected from over voltage, thus prolongs its life cycle.

B. *Maximum Power Point Tracking (MPPT) Algorithm*

On the other hand, Maximum Power Point Tracking (MPPT) is another type of controller algorithm. It is a solar charging algorithm for extracting maximum available power from PV module under certain conditions. The voltage at which PV module can produce maximum power is called maximum power point or peak power voltage [5]. Due to some conditions of the amount of sunlight, maximum power varies with solar radiation, ambient temperature and solar cell type and temperature. This translates the amount of energy harvested from the PV at maximum, thus making the charging of the batteries faster.

III. SYSTEM ARCHITECTURE AND METHOD

As reflected in Figure 1, the data mining process starts with the modeling of equation that is based on the training data. This data is the consequent of the information stored on the training database based on the historical data of the solar-agri terrain vehicle.

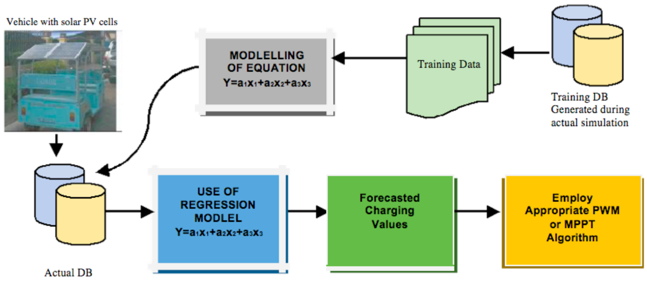

Fig. 1. Solar-Agri Terrain Vehicle with Data Mining

A. *Data Mining in the hybrid charging mechanism*

The Multiple Regression Equation was the basis to develop a model on the decision-making mechanism to switch between PWM and MPPT charging algorithms so it could optimize the battery charging of the solar vehicle. In this case the application area is in the agricultural vehicle with variety of land terrain, where sunlight is assumed to be insufficiently oriented to the PV panels installed on the vehicle due to its movements.

B. *Intelligent Charging Method*

Let Floating Voltage be at V_{fb}=minimum

1. Compute for the state of charge of the battery.

2. Detect and compute amount of sunlight in watts per square meter (watts/m^2).

3. Using electronic meter determine the amount of solar panel voltage (*V*) based on the three levels
   a. Low (voltage is minimum)
   b. Average (voltage is medium)
   c. High (voltage is at maximum)

4. Compute for the current (I) drawn by the PV as to the required charging *I* of the battery
   a. Low (amount of *I* is minimum)
   b. Average (amount of *I* is medium)
   c. High (amount of *I* is maximum)

5. Input the values in (2) and (3) to generate Regression Model, $Y=a+b_1x_1+b_2x_2$.

6. Determine the computed output and use the scale to decide between PWM and MPPT.

7. Check battery voltage status.

8. Loop on (1) to (7), until floating voltage V_{fb}=maximum is achieved.
9. End

C. *Prediction model based on Regression Equation*

The system will make use of two attributes, thus an equation expressed in (1) will be utilized for the computations. These attributes are expressed in x_1 and x_2, respectively.

$$Y=a+b_1x_1+b_2x_2 \quad (1)$$

The variable *Y* is a predicted model, while constant *a* is the dependent variable coefficient and b_1 and b_2 are the model factors computed based on the input values. While x_1 refers to the amount of sunlight (computed in watts per square meter) and x_2 is the current drawn for the PV cells.

D. *Simulation Environment*

The components used in the simulation include series of PV panels rated at 30 watts, 12 Volts with *Imax* of 1.6 A. The setup made use of 5 sets of 42 Ampere-Hour (AH) solar batteries connected in series resulting to a terminal voltage of 60 V. Two types of controller were used for testing the switching algorithm and these are PWM and MPPT type of controllers.

The data were collected through simulation of the electric vehicle with motor power of 800 watts and a load capacity of 300 kilograms. The data extraction was set at two modes, that is stationary and in motion, and the data was taken at three specific sampling points of a day with a total of 3 trials.

E. *Computation of the Prediction Model*

The following presents the computation for prediction model for one dependent attribute and two independent attributes. With the input of the training data for 10 sample points per day for a total of seven days, the researchers

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accumulated a total of 70 data samples and the model was computed and reflected in (4).

$$Y = a + b_1x_1+b_2x_2+...+b_nx_n \quad (2)$$
$$Y = 0.20 + 0.32x_1 - 0.40x_2 \quad (3)$$

For clarity of presentation, components *a, b_1 and b_2* are computed using (4), (5) and (6), respectively.

$$a = \overline{Y} - b\overline{X} \quad (4)$$

$$b_1 = \frac{(\sum x_2^2)(\sum x_1 y) - (\sum x_1x_2)(\sum x_2 y)}{(\sum x_1^2)(\sum x_2^2) - (\sum x_1x_2)^2} \quad (5)$$

$$b_2 = \frac{(\sum x_1^2)(\sum x_2 y) - (\sum x_1x_2)(\sum x_1 y)}{(\sum x_1^2)(\sum x_2^2) - (\sum x_1x_2)^2} \quad (6)$$

The computed values for *a*, b_1 and b_2 are then are entered into the multiple regression equation, which will result to the final model for predicting the state of charge of the vehicle battery.

Based on (5) and (6), values for b_1 and b_2 were computed and resulted to:

b_1 = 0.32
b_2 = -0.40

Coefficient *a* was computed using (4), which indicates two attributes in this case. These attributes are expressed in x_1 and x_2, respectively

With (4) used for computation, coefficient *a* yields:

a = 0.20

Thus, the prediction model based on the coefficient computed is given by:

$$Y = 0.20 + 0.32x_1 - 0.40x_2 \quad (7)$$

IV. SIMULATION RESULTS

A simulation was done using the parameters explained in section 3. In this simulation, the model was computed based on (2). The result becomes basis for the switching mechanism between PWM and MPPT charging algorithm. The actual data was captured and entered into the regression equation. The sample computation and table of results are presented below.

Table 1. Computed state of charge of solar-agri vehicle

Value			Predicted State of Charge		Algorithm Decision
Sample	Sunlight x_1	Current x_2	Y	Meaning	
1	1	1	0.92	Low	MPPT
2	2	1	1.24	Average	PWM
3	2	2	1.64	Average	PWM
4	3	3	2.36	High	PWM
5	2	3	2.04	High	PWM

Prediction of the State of Charge

Based on the actual readings, let the values for x_1 =3 and the x_2 =2.

Based on the model in (7), the predicted state of charge is computed as reflected in *Y*:

Y=0.198+0.319(3)-0.402(2), thus it yields

Y=0.35

This result implies that there is a low state of charge, thus the switching algorithm shall prefer MPPT algorithm. The data in Table 1 shows the actual values and its predicted state of charge based on the regression model and this becomes basis in deciding on whether to switch to PWM or MMPT.

Because MPPT performs fast charging with low input sunlight, the selection of MPPT at low state of charge is preferred. On the other hand, at average and high, PWM is selected to prevent possible overcharging until it achieves the floating voltage of the battery, thus protecting the storage medium and extending its life cycle. These results could be used for calibrating the charging device for electric/solar vehicle, thus optimizing the amount of energy harvested from the solar panels.

This could lead to the design and fabrication of improved charging device incorporating the rules generated in the findings of the study and the proposed switching algorithm that is appropriate for agricultural application, given its versatility in land terrain and moving positions.

V. CONCLUSION AND RECOMMENDATIONS

The proposed switching algorithm based on the computed regression model had demonstrated efficiency in charging state of electric vehicles. The algorithm for switching mode embedded two important charging techniques, which performed hybrid charging based on the predicted state of charge of the battery, thus providing efficient, safe and optimized system that could be implemented for solar-agricultural and autonomous vehicles.

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With the efficiency of the proposed system during the charging mode, there could be increased possibilities to operate the vehicle for longer hours. The future use of this paper is for the agricultural-terrain applications that will be based on the increased motor power installed on it. This may overcome the heterogeneity of the land and the amount of energy drawn from the solar panels due to vehicle motion.

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