Efficient Dual Mode Photovoltaic Power System for Improved Drive Span for Electric Vehicles

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Abstract: The problem of drive span maximization in electric vehicle is well studied. There exist number of approaches around the problem which uses residual energy and sleep mode as key in maximizing the drive span. However, they suffer to achieve higher performance in drive span maximization. This article presents a novel Dual Model Photovoltaic Power System Based Drive Span Maximization Model (DPDSM). The model is focused on maximizing the storage of voltage in the PV cells and utilizing maximum battery supply. The model generates the voltage from the photovoltaic system and regulates the power to the electric vehicle. The model has been connected with number of photovoltaic cells, which has been connected in serial. Using them, the required voltage has been regulated to the electric motor. In another mode, the residual voltage of the vehicle battery has been changed to discharge mode which support the regulation of voltage for the vehicle. The dual mode photovoltaic power system regulates effective power for the electric vehicle continuously with less voltage loss.

Keywords: Photovoltaic System, Drive Span, EV, DPDSM, Dual Mode.

1. Introduction:

The growing use of electricity and electric vehicles has challenge the manufacturer in providing higher drive span. The increased fuel cost encourages the consumers in buying electric vehicles. The use of electric vehicle supports the reduction of environment pollution and has been encouraged by various countries. However, there are number of issues can be named in using electric vehicles. The first issue is the cost of vehicle, when compare to the petrol and diesel vehicle. On the other side, the damage of battery in the electric vehicle is higher compare to other type of vehicle.

Apart from the damage cost, the drive span is the most dominant concern in the industry. By providing higher drive span, the cost of driving gets reduced and the performance of electric vehicle gets improved. To maximize the drive span of the electric vehicle, there are number of approaches handled in literature. Some of the method uses multiple batteries and some of them use the photovoltaic systems as the backup one. However, they suffer to achieve higher performance in drive span maximization.

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The drive span of the electric vehicle can be improved by adapting multiple power systems in one channel and by stipulating the systems between various modes of operation, the performance of the electric vehicle can be improved. In this way, an efficient Dual mode Photovoltaic Power System (DPDSM) is presented in this article [16]. The model is focused on utilizing the output voltage of pv system in full and reducing the voltage loss. The model combines the Pv system with the battery of electric vehicle. It works on two mode, where in the first mode, the electric voltage produced by the PV system has been directed through the cells of PV system and directly given to the electric vehicle [15]. If the voltage produced by the PV system is higher than the required voltage, then it triggers the unused cells of PV system and battery of electric vehicle to get charged. On the other mode, the voltage required for the vehicle has been used from the battery. By doing so, the voltage loss gets reduced and efficiency of electric vehicle gets improved [14].

2. Related Works:

There exist number of approaches towards power regulation in Electric vehicles and this section details some of the methods around the problem.

An intelligent energy management system is presented in [1], to support flexible operation of grid connected solar powered electric vehicle (EV). The method uses the constraints like PV availability, grid loading and EV charging load data. The method uses a Markov decision process (MDP) to perform vehicle control. A disturbance observer (DOB)-based model predictive voltage control (MPVC) is presented in [2] to support electric vehicle.

A particle swarm optimization (PSO) based control law generation model is presented in [3], which generates maximum voltage from photovoltaic generator (GPV) and applies PSO to regulate the supply to the vehicle. A multibattery block module (MBM) topology is presented in [4], to support electric vehicles which uses multi-battery block module and photovoltaic (PV) panel into an asymmetrical half-bridge (AHB) converter, to supply a multilevel bus voltage for the SRM drive. A tracking absorption strategy is presented in [5], which adjust the charging process of electric vehicle through electric vehicle aggregator (EVA) and uses soft actor-critic (SAC) algorithm in scheduling the process.

A electric-drive-reconstructed onboard charger (EDROC) is presented in [6], which has six phase machine drive and power traction inverter to leverage the charging process.

An synchronous MPPT over DPP topology is presented in [7], to facilitate more targeted decoupling and reduce the difficulty and complexity of decoupling.

Along short-term memory (LSTM) recurrent neural network (RNN) based model is presented in [8], to schedule charging and discharging of number of EVs in the model.

A three stage voltage allocation and distribution model is presented in [9], to support electric two wheelers in charging station. A power grid voltage stability analysis framework is presented in [10], which analyze power generation and load demand with Monte Carlo simulation. The driving data of Toyota prius car has been demonstrated and analyzed in [11]. An optimal scheduling model is presented in [12], which handles the distribution mobile energy storage systems. A hierarchical coordination framework is presented in [13], to manage domestic load using photovoltaic (PV) units, battery-energy-storage-systems (BESs) and electric vehicles (EVs).

A bidirectional dc converter (Bi-C) is presented in [14], to improve dynamic stability and provide a high-quality power supply for EVs.

3. Dual Mode Photovoltaic Power System Based Drive Span Maximization Model (DPDSM):

The model is focused on maximizing the storage of voltage in the PV cells and utilizing maximum battery supply. The model generates the voltage from the photovoltaic system and regulates the power to the electric vehicle. The model has been connected with number of photovoltaic cells, which has been connected in serial. Using them, the required voltage has been regulated to the electric motor. In another mode, the residual voltage of the vehicle battery has been changed to discharge mode which support the regulation of voltage for the vehicle. To perform this, the method computes Vehicle Support Voltage (VSV) at each duty cycle. Based on the value of VSV, the method decides the mode of the circuit. If the value of VSV is higher than the input voltage then the circuit is triggered to discharge mode where in the other case, it has been triggered to charging mode. The detailed model is presented in this part.

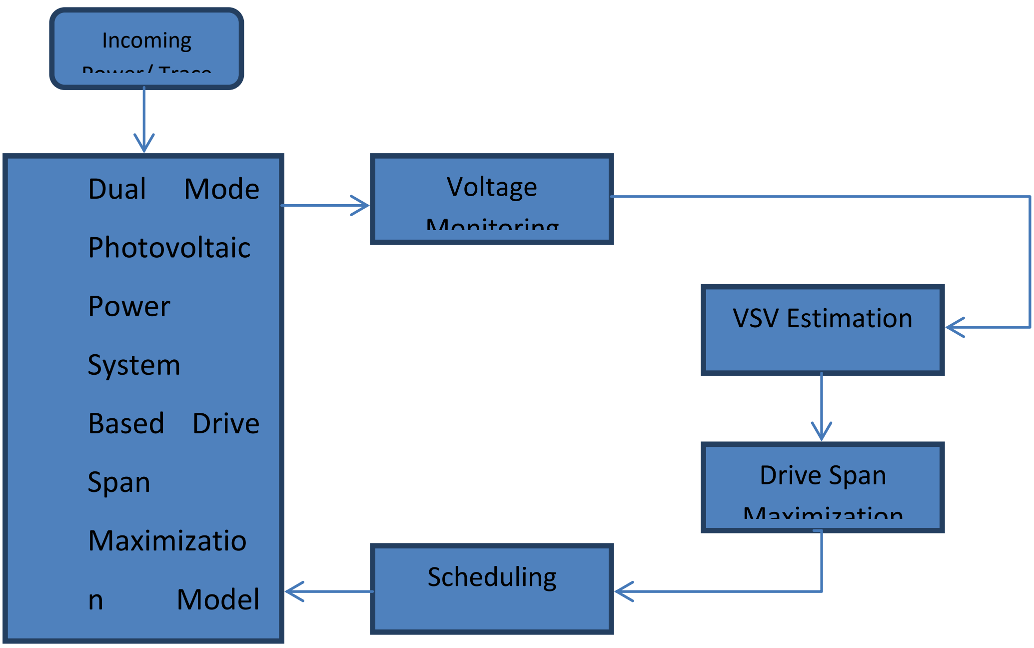

Figure 1: Block Diagram of Proposed DPDSM model

The working diagram of proposed DPDSM model is presented in Figure 1.

Voltage Monitoring:

The proposed model monitors the incoming voltage from the PV system. The photovoltaic system is fabricated with number of PV cells and connected with the PV panel. The electricity produced by the panel is charged with the PV cell. At each duty cycle, the method monitors the voltage being produced. Also, the PV system has been connected with the battery of EV. By monitoring the voltage produced, the method schedules the mode of different PV cells and battery of EV to support effective driving of the vehicle.

Algorithm:
Given: Power Trace PT
Obtain: Null
Start
Read Power Trace PT.

While true
Receive voltage from each PV cell.
VSV= Perform VSV Estimation.
Dsv = Perform Drive Span Maximization
Perform scheduling.
End
Stop

The voltage monitoring algorithm monitor the incoming voltage from the PV cells and based on that the method performs VSV estimation and drive span maximization to schedule the PV cells towards effective driving of EV.

VSV Estimation:

The vehicle support voltage (VSV) represents the voltage required for the electric vehicle. It is measured based on the voltage produced by different PV cells and residual voltage of the electric vehicle. At each duty cycle, the value of VSV is measured according to the voltage being produced by the PV cells. Using these values, the method compute VSV value to support effective vehicle driving.

Algorithm:
Given: Pv Cells Pvs
Obtain: VSV
Start
Read Pvs.
For each pv cell p
Compute Cell level VSV as CVSV = $\frac{Pv.InputVolt}{EV.VoltsRequired} \times \mu$
Where $\mu - voltage\ constant$
End
Compute VSV = $\frac{\sum CVSV}{size(Pvs)}$
Stop

The VSV estimation algorithm computes the vehicle support voltage from the volts produced by the PV cells. Based on the value of VSV, the method decides the mode of the cells and supports drive span maximization.

Drive Span Maximization:

The drive span maximization algorithm reads the VSV value of the pv cells. Based on the value of VSV, the method computes the surplus voltage Value (SVV) according to the set of voltage in all the pv cells and required voltage of vehicle. Based on the value of SVV, the method selects set of pv cells for discharge mode and rest of them are allowed to charging mode. Such assigned modes are used to schedule the cells of pv system and battery of the vehicle towards drive span maximization.

Algorithm:
Given: VSV, Pvs
Obtain: Charging set Cs and Discharging set Ds
Start
Read Vsv and Pvs.
Compute Svv = VSV-Voltage_Required
If SVV> Th then
For each cell pv
If Pv.voltage>($\frac{1}{6}Svv$) then
Add to charging set Cs = $(\sum Pv \in Cs) \cup pv$
Else
Add to discharging set ds = $(\sum Pv \in ds) \cup pv$

End
End
Assign vehicle battery to charging mode.
Else
Assign vehicle battery to discharge mode.
End
Stop

The drive span maximization algorithm computes svv value for the cycle for the pv cells and based on that the method identifies the mode of the cells for the cycle.

Scheduling:

The scheduling scheme reads the charging cells and discharging cells set provided. The method schedules the cells according to the mode given. The cells of the charging set are assigned to charging mode and the cells of the discharging set have been assigned with discharging mode.

4. Results and Discussion:

The proposed Dual Mode Photovoltaic Power System Based Drive Span Maximization Model (DPDSM) has been implemented with Simulink. The performance of the model has been evaluated under various parameters and presented in this section.

Parameter	Value
Tool Used	Simulink
No of cells	100
Time	10 minutes

Table 1: Experimental Details

The experimental details used towards performance analysis are presented in table 1.

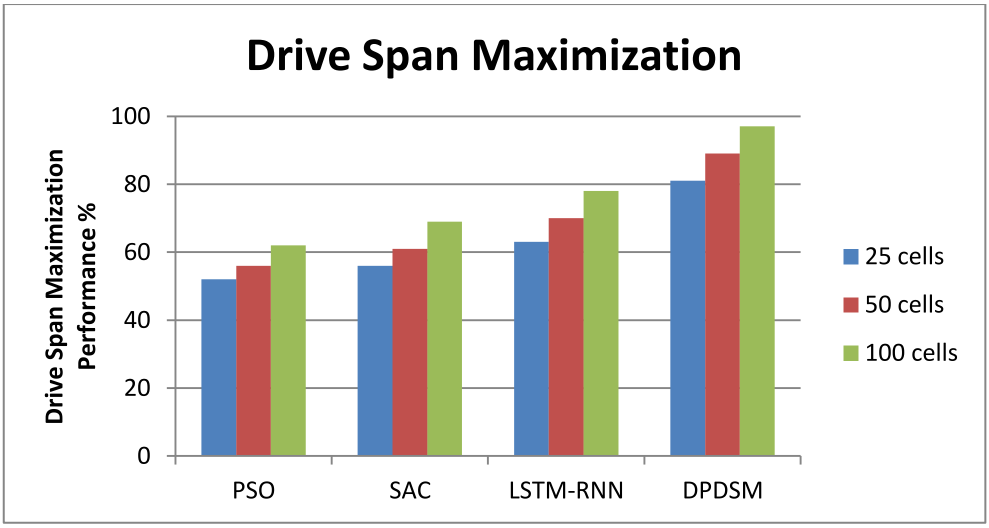

Figure 2: Drive Span Maximization Performance

The performance of method in drive span maximization is measured and presented in Figure 2. The DPDSM model introduces higher performance than others.

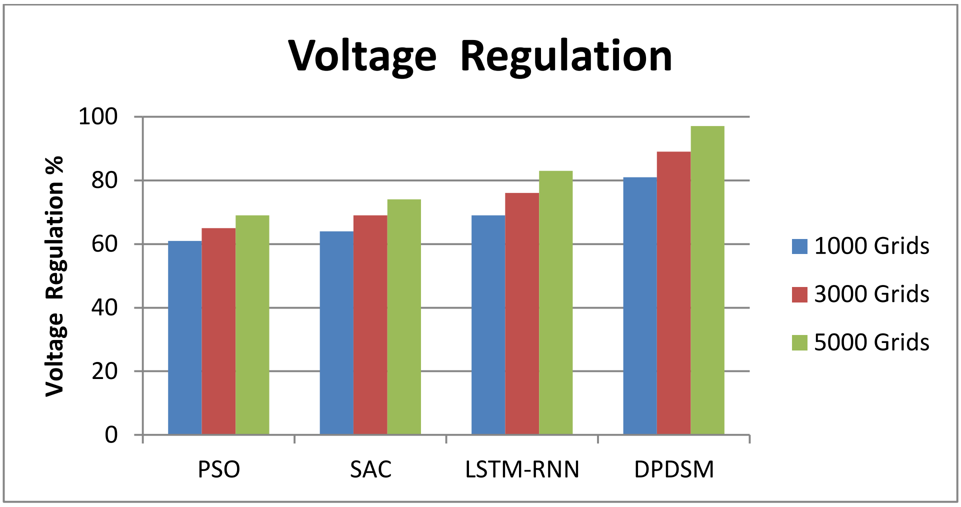

Figure 2: Voltage Regulation Performance

The performance of methods in voltage regulation is measured and presented Figure 3. The proposed DPDSM method produces higher voltage regulation performance than others.

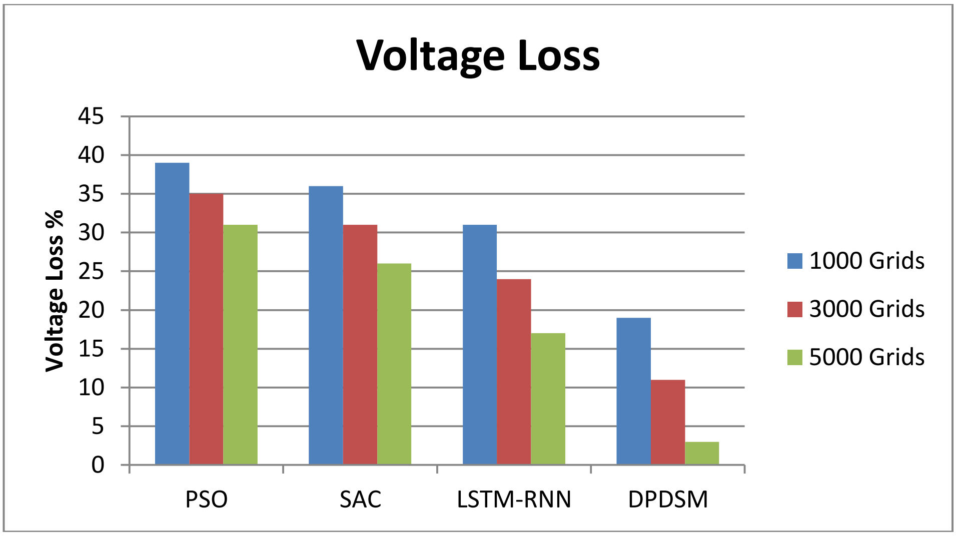

Figure 4: Voltage Loss

The voltage loss introduced by various models is measured and compared in Figure 4. The DPDSM model introduces less voltage loss than other models.

5. Conclusion:

This paper presented a novel Dual Mode Photovoltaic Power System Based Drive Span Maximization Model (DPDSM). The model is focused on maximizing the storage of voltage in the PV cells and utilizing maximum battery supply. The model generates the voltage from the photovoltaic system and regulates the power to the electric vehicle. The model has been connected with number of photovoltaic cells, which has been connected in serial. Using them, the required voltage has been regulated to the electric motor. In another mode, the residual voltage of the vehicle battery has been changed to discharge mode which support the regulation of voltage for the vehicle. To perform this, the method computes Vehicle Support Voltage (VSV) at each duty cycle. Based on the value of VSV, the method decides the mode of the circuit. If the value of VSV is higher than the input voltage then the circuit is triggered to discharge mode where in the other case, it has been triggered to charging mode. The proposed method improves the performance of drive span maximization and voltage regulation with less voltage loss.

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