Power Efficient Voltage Regulation System for Improved Power Generation in Wind Mills

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Abstract: The power distribution systems with the wind energy backup have been well studied. There exist number of approaches in regulating required voltage for the electrical devices which uses only few parameters like number of connections, number of devices and residual voltage in various sources. However, they suffer to achieve higher performance in voltage regulation. To handle this issue, an Power Efficient Voltage Regulation Model (PEVRM) is presented in this article. The model has number of wind sources connected to the power grids of the distribution system. By monitoring the load produced by various wind sources and the residual energy of various power grids, the method perform voltage regulation. With the features of power trace maintained and the current peak load produced by various wind sources with the required output voltage, the method performs voltage regulation. The selection of wind source and power grid plays vital role in achieving higher performance in voltage regulation. To perform this, the method identifies set of grid sources and their features in terms of voltage available. Similarly, the set of wind sources are identified and their features are extracted. Using this information, the method computes the value of Wind Stability Support (WSS) and Grid Stability Support (GSS) and Peak Load Support (PLS). Using these measures, the method identifies the set of grid sources and wind sources to support the current cycle and perform voltage regulation. The proposed method improves the performance of voltage regulation and power stability.

Keywords: Wind Energy, Voltage Regulation, Power Grid, WSS, GSS, PLS, PEVRM.

1. Introduction:

The utilization of electricity has been increased due to the growing use of electrical devices. The electric power has been generated from limited source like wind, solar, thermal, and atomic sources. However, the sources other than wind and solar are available only for a limited period of the year. But for a smooth functioning of the electric

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devices, it is necessary to provide constant voltage for the device. It must be ensured that the device is getting constant voltage, so that it would function in a proper manner.

The power has been distributed for the various connections of any locality or industry through the power distribution system. The power distribution system is connected with the power grids and power sources. When the power source generation units produces output voltage, it has been received by the power distribution units and the grids are used to store the voltage available. But in reality, the power generation units would not produce a constant voltage and there will be fluctuation in the output voltage produced. However, the distribution unit has the responsibility in maintaining the steady output voltage. To perform such voltage regulation, there exist numbers of models, which consider the number of connection, number of units consumed, and number of devices using the voltage and so on. However, the method does not produce the efficient regulation.

Wind source is the most dominant source which is available throughout the year. By implanting the wind mills in different location where the wind flow is higher, they can be connected with the power distribution systems. The energy produced by the wind mills would be stored in the power grid units and the same has been used to regulate the steady voltage for the electrical system.

To maximize the performance of voltage regulation and power stability, a Power Efficient Voltage Regulation Model (PEVRM) is presented in this article. The model has connected with different wind sources and power grid units. The voltages produced by the wind sources are stored in the power grid units. Based on the input voltage, and the output voltage required, the model identifies set of grid units to support voltage regulation. The identification of such grid units is performed by measuring Wind Stability Support (WSS) and Grid Stability Support (GSS) and Peak Load Support (PLS). The WSS value is measured according to the average voltage produced by any wind source and GSS value is measured based on the average regulated voltage and residual voltage. Also, the method computes PLS value according to the value of WSS and GSS. With the value of PLS, the method identifies set of grid units to perform voltage regulation. The detailed working of the model has been structured in the next section.

2. Related Works:

Number of approaches is discussed in literature towards power stability and voltage regulation. This section details set of methods around the problem.

A superconducting magnetic energy storage (SMES) integrated current-source DC/DC converter (CSDC) (SMES-CSDC) is presented in [1], which performs voltage stabilization in multi-farious transient disturbances and power regulation under wind speed variations. A two-stage optimization of superconducting magnetic energy storage (SMES) integrated into hybrid wind/photovoltaic (PV) system is presented in [2] towards effective stabilization. A doubly fed induction generator (DFIG)-based wind turbine systems is presented in [3]. A grid-connected solar photovoltaic and wind energy (PV-WE) system is presented in [4] towards power enhancement.

A wind power medium-voltage direct-current (MVDC) transmission system is presented in [5], which realize the DC transmission of offshore wind power and eliminate offshore platforms.

A impedance model of Grid connected inverters is presented in [6]. A frequency regulation and stabilization control architecture is presented in [7] to support wind turbine generator (WTG) integrated power grid.

A real time field reconstruction model is presented in [8], which analyze the distribution of wind speed and direction towards power stabilization. A doubly fed induction generator (DFIG)-based wind farm via retarded sampled-data control (RSDC) is presented in [8], to support power stabilization.

A nonparallel distribution compensation (PDC) control is proposed in [9], to support permanent magnet synchronous generator (PMSG)-based wind energy conversion systems (WECS).

A hybrid ac-dc impedance model with network partitioning method is presented in [11], to analyze the stability of the point-to-point HVdc system. A reinforcement learning-based adaptive optimal fuzzy controller is presented in [12], to maximize the power stabilization.

3. Power Efficient Voltage Regulation Model (PEVRM):

The Power Efficient Voltage Regulation Model (PEVRM) has number of wind sources connected to the power grids of the distribution system. By monitoring the load produced by various wind sources and the residual energy of various power grids, the method perform voltage regulation [13]. With the features of power trace maintained and the current peak load produced by various wind sources with the required output voltage, the method performs voltage regulation. To perform this, the method identifies set of grid sources and their features in terms of voltage available. Similarly, the set of wind sources are identified and their features are extracted. Using this information, the method computes the value of Wind Stability Support (WSS) and Grid Stability Support (GSS) and Peak Load Support (PLS) [14]. Using these measures, the method identifies the set of grid sources and wind sources to support the current cycle and perform voltage regulation.

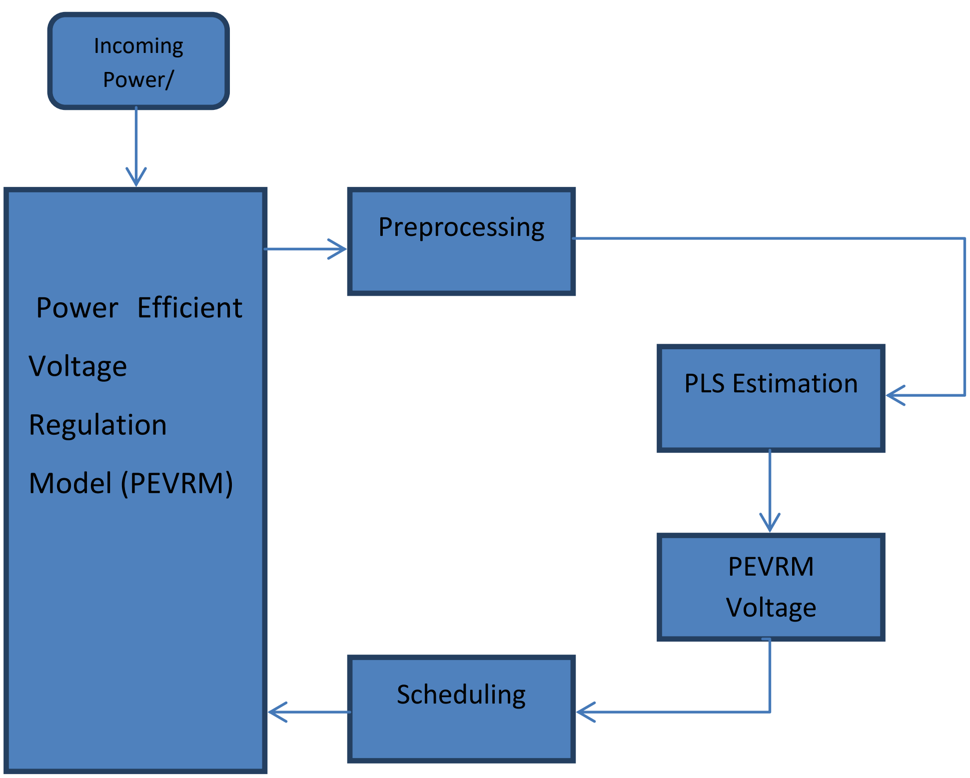

Figure 1: Architecture of PEVRM Voltage Regulation Model

The working model of proposed PEVRM model is presented in Figure 1, where the functions of the model are detailed in this section.

Preprocessing:

Preprocessing is the process of normalizing the power trace available. The proposed model performs voltage regulation according to the power trace available. It has number of features at each record. There will be missing values and incomplete traces in the data set. It is necessary to eliminate the noise from the data set. It has been performed by preprocessing the trace available [15]. To perform this, the set of features in the records of the trace is identified initially. Further, the records are traversed and verified for the presence of all features and values. If there is any record identified with missing features then it has been removed from the data set. Such noise removed data set has been used to perform voltage regulation.

Algorithm:
Given : Power Traces PT
Obtain: Preprocessed Trace PrT
Start

Read PT.

Initialize feature set Efs = $(\sum_{i=1}^{size(PT)} Features(PT(i) \ni Efs) \cup EFS$

For each trace T

If T $\in \forall Features(Efs) then$ has all features of Efs

PrT =$(\sum Traces \in prT) \cup T$

Else

PT = PT$\cap T$

End

End

Stop

The preprocessing algorithm reads the power trace data set available and identifies the set of features in the data set. According to the feature set identified, the method verifies the completeness of all the records and removes the incomplete one from the set. Such noise removed data set has been used to perform voltage regulation.

PLS Estimation:

The peak load support (PLS) is the measure which represent the suitability any sequence of grid units in achieving greater voltage regulation. The method receives the wind source and grid unit and identifies the trace of the grid unit given. According to the trace of the grid unit, the method computes the value of Wind Stability Support (WSS) and Grid Stability Support (GSS) and Peak Load Support (PLS). Estimated PLS value has been used to perform voltage regulation.

Algorithm:
Given: Power Trace PT, Grid G, wind source ws
Obtain: PLS
Start

Read PT, G, ws.

Collect grid traces GT = $\sum_{i=1}^{size(PT)} PT(i).gridset \in G$

Collect wind source set Wis =$\sum_{i=1}^{size(PT)} PT(i).windsource == ws$

$$\text{Compute WSS} = \frac{\sum_{i=1}^{size(wis)} Sum(wis(i).windpower) \Big/ size(Wis)}{\sum_{i=1}^{size(wis)} Sum(wis(i).outputpower) \Big/ size(Wis)}$$

$$\text{Compute GSS} = \frac{\sum_{i=1}^{size(GT)} Sum(GT(i).regulatedpower) \Big/ size(GT)}{\sum_{i=1}^{size(GT)} Sum(GT(i).outputpower) \Big/ size(GT)} \times \frac{\sum_{i=1}^{size(GT)} Sum(GT(i).inputpower)}{Size(GT)}$$

Compute PLS = WSS×GSS

Stop

The PLS estimation algorithm computes the value of WSS and GSS values. Based on the value measured, the method computes PLS value. Estimated PLS value has been used to perform voltage regulation and scheduling.

PEVRM Voltage Regulation:

The power efficient voltage regulation model monitor the incoming voltage from the wind power sources. At each cycle, according to the power received from the wind power sources the method perform voltage regulation. To perform this, the set of idle grid units are identified. For the grid units identified from the previous cycle condition, the method computes PLS value for each power source with grid unit. Based on the PLS value, a small set of wind source and grid units are selected for the voltage regulation. Selected grid sources are scheduled to support effective voltage regulation.

Algorithm:
Given: Power Trace PT
Obtain: Null
Start
Read PT.
While true
Iv = Receive input voltage from wind sources.
Identify set of wind sources Ws = $\sum_{i=1}^{size(PT)} PT(i).windsource$
Identify set of grid source gs =$\sum_{i=1}^{size(PT)} PT(i).gridunits$
Identify idle grids Ig = $\sum_{i=1}^{size(Gs)} Gs(i).gridunits.state == idle$
For each wind source w
For each grid unit g
PLS = Estimate PLS (PT, g,w)

End
End
Grid units gus = Choose k maximum PLS valued grid units.
Perform scheduling.
Wait for next cycle.
End
Stop

The PEVRM voltage regulation model computes the PLS value for various grid units which are idle at the previous cycle. Based on that, a small set of grid units are selected for discharge and the rest has been scheduled to be on charging mode.

4. Results and Discussion:

The proposed Power Efficient Voltage Regulation Model (PEVRM) 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.

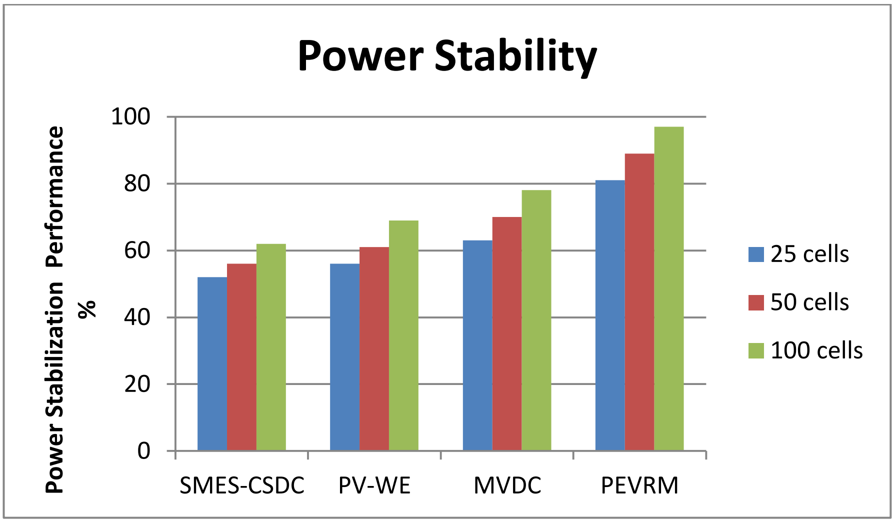

Figure 2: Power Stability Performance

The performance of method in power stabilization is measured and presented in Figure 2. The PEVRM model introduces higher performance than others.

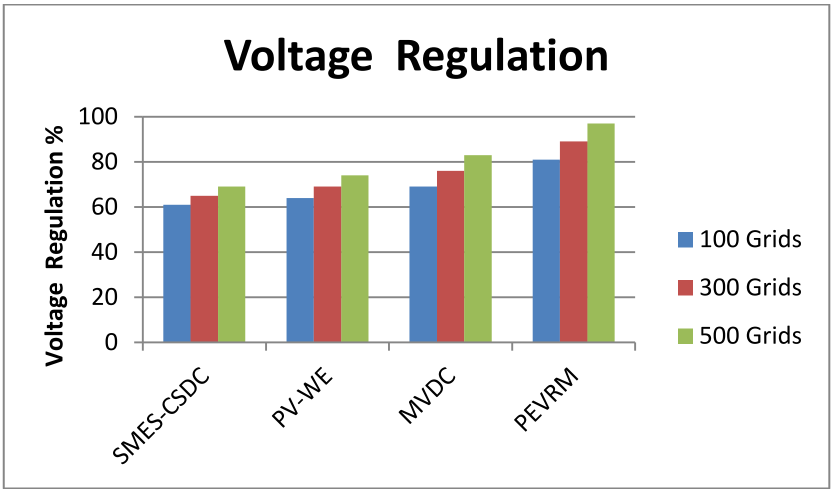

Figure 2: Voltage Regulation Performance

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

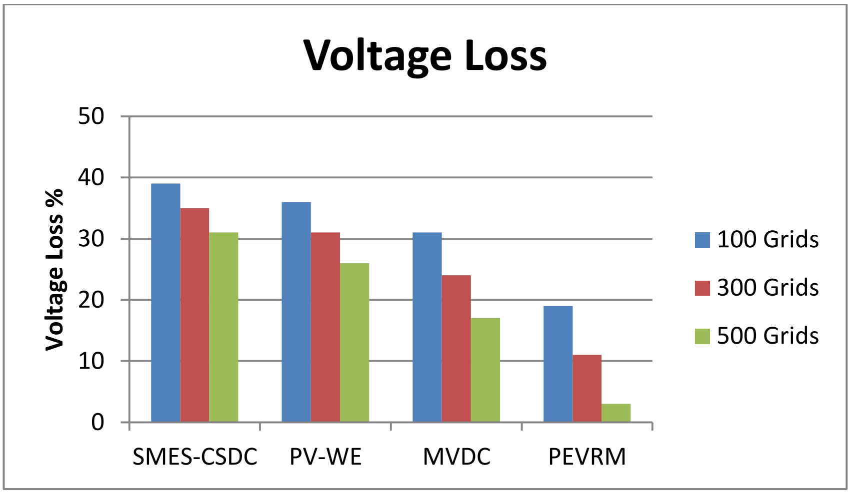

Figure 4: Voltage Loss

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

5. Conclusion:

This paper presented a Power Efficient Voltage Regulation Model (PEVRM) towards voltage stabilization in wind mills. By monitoring the load produced by various wind sources and the residual energy of various power grids, the method perform voltage regulation. To perform this, the method identifies set of grid sources and their features in terms of voltage available. Similarly, the set of wind sources are identified and their features are extracted. Using this information, the method computes the value of Wind Stability Support (WSS) and Grid Stability Support (GSS) and Peak Load Support (PLS). Using these measures, the method identifies the set of grid sources and wind sources to support the current cycle and perform voltage regulation. The proposed method improves the performance of power stability and voltage regulation.

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