Power and Energy Storage of Wind Energy in Distributed Generation Network

Alamzeb Shahzad¹, Waleed Jan², Muhammad Aamir Aman³, Ehtesham-ul-Haq⁴, Mehr E Munir⁵

¹, ², ³, ⁴, ⁵Department of Electrical Engineering, Iqra National University, Peshawar 25000, Pakistan

*Corresponding author: Alamzeb Shahzad, https://doi.org/10.26782/jmcms.2019.06.00014

Abstract

Power is a necessary tool for modern civilization. All the modern achievements and technology have made man achieve more and more day by day but use of fossil fuels tends to be limited. On other hand, technologies and techniques are being developed to use natural renewable sources in order to fulfill power and energy demand. Distributed Generation is part of new renewable energy trend in which different grid resources are added to meet user end requirements. This paper presents an approach to limit the power storage from wind energy while working with voltage levels. The study is performed in mainly two levels. First the wind profile is studied with load requirements and then detailed control is performed for optimal power flow (OPF). It is found that storages can be changed via user requirement while also depending upon threshold of DG network.

Keywords: Wind Energy, Energy Storage, Distributed Generation, Wind Energy Farm, Power Generation, Power flow

I. Introduction

In Renewable energy market, Network management is considered as key factor in terms of performance. Its storage, combination of sources to meet user end requirements without the interruption of power is a critical factor to be considered while planning a distributed generation network. In a DG network it is necessary to restrict the generation for voltage and congestion issues. For such restrictions modern analytical and scientific tools are required [I-III].

Storing energy is the crucial factor of a DG system. Storing capacity defines the ability of the energy to be stored which will further will be used and distributed at user end. Storing energy is considered to primary factor that will define a DG performance since in real time processing DG can be released when limitations are not obligatory. This can also lead to regulate voltage levels and congestions as energy storage ability allows user to add reactive power. In context and real time, storing the
energy requires appropriate size structure which assimilates the characteristics to capture actual power and its needs in the DG [VI-VIII].

In this paper, trial and error (TAE) based approach is used for storing the energy. Storages defined at specific points are taken and considered and it is a tradeoff in between the cost or operations and its facility. TAE is approachable as it requires large size area and combinations to be considered with different capabilities but with increased facilities rate, this becomes a hard task to implement. [IX-XI].

Techniques to be considered for energy storages include algorithm consenting extra systematic study of compatible examine space, and study of AC optimal flow [XII-XIV]. While storing energy, one necessary step that should be considered is how to discharge such amount of energy that does not damage the capacity of storage devices which technique mentioned in [XIV] fails to do so. Storing these devices in the facility is to be handled with great care and plan since this also leads to extra cost which usually can lead a DG project to be costly and in renewable energy market cost analysis is crucial as capital investment is always high and designers and researches always tend to produce high quality network while keeping the cost low [XIII-XIV].

This paper presents the wind energy storage facility architecture comprising on two stages as how to effectively store wind energy and is charge and discharge intervals. Section one considers Introduction, after which comes storage architecture in two stages third comes Mathematical formulation followed by designed 33KV plant with DG connected and in last comes conclusion.

II. Storage Architecture

While discussing the power and energy storage of wind energy potential, a proper scale has to be chosen in terms of time duration which can be a month, year or decade. With time it is necessary to also consider the supply and demand situation of the network, peak hours, energy generation and load conditions. We can say that the entire storage layout design for optimization procedure depends upon how much data of energy time scale is present. Figure 1 shows our design strategy in 2 levels which is planning and control.

![Figure 1. Proposed Architecture.](image-url)
The multi period AC OPF determines the required storage capacities capable enough to minimize the wind curtailments at certain points and it is achieved in continuously studying the time intervals over a specific interval of time. The planning stage is composed of as a balance in between the effective characteristics and timely demand data on hourly basis.

In second stage, the proposed planned scheme is monitored and evaluated and implemented in order to control energy storage. In this stage, the duration of one minute control cycle is used. This is achieved using a single algorithm designed to evaluate control cycle by accessing the data provided in stage 1.

After the second stage, if the curtailment level is not found in the desired value, this process is applied again all over with new values to be evaluated until the desired and actual curtailment falls into the tolerance limit.

### III. Mathematical Modeling

As the cost can dramatically increase and decrease according to storage capacity so the first stage in which the energy storage is formulated usually focuses on demand hours specially.

\[
\min \sum_{ta \in TA} P_R R_{ta}^{evaluated} + P_G G_{ta}^{evaluated}
\]  

(1)

Which represents the operational costs and power evaluated. Generally half of the rating cost is always considered added in terms of cost.

Then comes the injection and discharge of power in storages. Negative sign indicate discharging intervals.

\[-O_{ta}^{evaluated} \leq I_{ta,t} \leq O_{ta}^{evaluated}; \forall ta, t\]

(2)

The noteworthy point here is that technology of storage devices change gradually with respect to time and with updated technology, the power restrictions changes.

In this method, instead of two variables, a single variable is modeled is studied which is useful since in previous studies charging or discharging one at a time was studied and in proposed model charging and discharging is studied instantaneously. In this continuous charge and discharge power loss also occurs which can be calculated by

\[\Delta R_{ta}^{evaluated} = \left\{ \begin{array}{ll} -I_{ta,t} & \text{Eff discharge } I_{ta,t} \geq 0 \\ I_{ta,t} & \text{Eff charge } I_{ta,t} < 0 \end{array} \right\} \forall ta, t\]

(3)

\[\Delta R_{ta}^{evaluated} = R_{ta}^{(0)} + \sum_n n = 1\]

(4)
In order to preserve and maintain the battery life span power is discharge at certain battery level known as threshold limit below which discharging is not adequate so the power stored is held in between this range.

\[(1 - T_o L^{max}) R_{ta}^{evaluated} \leq R_{ta}^{preserve} \leq R_{ta}^{evaluated}, \forall t_a, t\] (5)

Both the corresponding power saving schemes are designed to validate reactive power in terms of inoculation and captivation not going beyond apparent power. Here the point to be noted is that for storage facility power factor angle must be in such value that the range of device covers it.

\[(I_{ta,t})^2 + (I_{t_a,t}) \leq (G_{ta}^{evaluated})^2, \forall t_a, t\] (6)

In distributed generation, sources covers the power output of the overall system and it should be kept in mind to handle such systems with extreme care since the output of the power plant changes with respect to time and voltages should be kept above threshold limits. For the wind power output and condensed power.

\[\beta_{m,t} = \beta_{m}^{evaluated} - \beta_{m,t}^{curl}\] (7)

III. Storage Modeling for the proposed 33KV station

![Figure 2. 33 KV designed architecture network](image-url)
The proposed network designed has four Distributed generation plants attached at 4 buses with 38.7MW of capacity in general. In order to analyze 1 minute cycle the total of thirty minute analysis has been analyzed from customers as demand of power diverse at different times of a day. Also the wind profile has been observe from the data of early months in Pakistan. The language proposed in [14] has been used to solve multi period OCF. Figure 3 and 4 shows the power flow in controlling 5.9MW plant and the collected WP and storage size.

At no load, the total resultant curtailment by analyzing minute by minute profile is 39.95% of the available 132MW available source with max curtailment at any instantaneous of 6.2%.

We have considered lithium battery to be analyzed since its charging and discharging efficiency ranges in 89% while in storing operation, in early hours of the day there is congestion in lines at certain bus bars and at some parts of the day the storage is adept enough of dealing the congestion matter. Table 1 shows the Data granularity of the storage. Table 2 shows the corresponding curtailment levels.
Table 1. Storage sizes

| MVA | MWH |
|-----|-----|
| 1   | 4   |
| 2   | 7   |
| 3   | 10  |
| 4   | 13  |
| 5   | 17  |
| 6   | 19  |

Table 2. Corresponding Curtailment Levels

| 1 Hour | 60 Seconds | Error |
|--------|-------------|-------|
| 27.6   | 34.7        | 5.5   |
| 22.4   | 29.8        | 3.0   |
| 25.6   | 22.3        | 2.2   |
| 21.2   | 26.6        | 2.1   |
| 19.1   | 21.7        | 0.9   |
| 17.7   | 19.3        | 1.2   |

The subsequent curtailment by the optimal process of storage and the 6-MW DG plant is 30% 3.4Mwh which is a noteworthy drop from the former percentage found by only smearing curtailment.

IV. Conclusion

This paper facilitates the minimum energy storing criteria from wind power DG power plant by studying the wind profiles on timely basis and for that two stage process was defined in which the first stage consisted on planning and second stage consisted on controlling the energy. It was found that hourly profiles should not be taken lightly since this can undervalue storage sizes. This charging and discharging profiles can be extend to future case studies from different area with DG of higher rating.

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