Automated Dispatch of Wind Power on Microgrid for Voltage Regulation

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Abstract: The variability of wind power generation adversely affects the grid conditions and the utilities find it challenging to accommodate variations in the injected wind power. To resolve this issue utilities impose curtailment of wind power generation. Demand side management (DSM) strategies have gained popularity among utilities in recent years. An advanced Demand Response (DR) scheme known as Demand Dispatch (DD) enable utilities to reshape demand curve to closely follow generation. An automated DD strategy is proposed as a solution to the issues related to high penetration of wind turbine generators (WTG) on micro grid. It basically balances the WTG power injection with real time controlled dispatchable loads. DD adopts smart communication for real time data collection as well as for dispatchable load management. A field implementation of DD in maintaining voltage stability in a DC microgrid with micro-WTG (m-WTG) is studied. The experiment results presented validate the scheme.

Keywords: Microgrid; wind electric generator; real time data communication; demand dispatch

Introduction

Environmental degradation and depletion of fossil fuels enhanced the development of renewable energy (RE) systems. Though environmentally benign, RE sources in general and wind power in particular is varying in nature and uncontrollable too. Fluctuating wind power penetration on electric power grid has adverse effects such as voltage fluctuation and frequency excursion on the grid [1-2]. Such irregularities challenge generation scheduling and make system operation complex. When power evacuation from wind farms becomes difficult, utilities are forced to curtail wind power generation [3-4]. Yet there is a need to accommodate higher RE penetration on power grids in order to mitigate the dual challenge of climate change on one side and power demand on the other. For example, the intended nationally determined contribution (INDC) of India demands capacity addition of wind power plants [6] by more than 100% in five years from 2017. Energy storage based schemes have been proposed by researchers to compensate the variability in wind power generation [2, 6-8]. Electric Vehicles were identified by a few researchers as a promising medium for distributed energy storage [9-13]. But large number of distributed energy storage systems increases the system cost, yet the operational complexity is not reduced too.

In 2008 Federal Electricity Regulatory Commission (FERC) introduced demand response (DR) [14], through which customers on electric utilities would voluntarily participate in load reduction. DR programs are a big success in reducing peak power demand [14], but it cannot guarantee absorption of excess generation when required. In such scenario an advanced version of DR called demand dispatch (DD) [13, 15] could be useful. Consumer load that can change their consumption pattern, upon request from utility is called Dispatchable Load (DL). DD makes use of DLs and information and communication technology (ICT) in reshaping the demand curve. The utility need to aggregate and precisely control such loads for effective DD operation. DD offers full capabilities of demand side management (DSM), with which the utility can control DLs to exactly match a varying RE generation. DLs could be in the range of a few kilo Watts to Mega Watts and their response
time could be from a few milliseconds to seconds [15]. The utility has to aggregate the scattered DLs and connect or disconnect these in synchronization with the wind power injection so as to nullify the effect of the latter. Bulk energy storage units like battery banks and pumped hydro systems too can actively participate in DD as DLs. The advancements in Smart Grid (SG) technology [16-18] facilitate the real time bi-directional communication needed for DD. The study presented in this paper finds DD as a promising solution for handling the fluctuations in power generation under high wind penetration.

This paper reports an investigation on DD, for voltage control in an autonomous DC microgrid solely powered by wind. This is a real time on-field study that uses a micro Wind Turbine Generator (m-WTG) installed on roof top and is powered by natural wind. The on-field study considered operating conditions naturally prevailed at the time of investigation.

Proposed DD Strategy

Electric power utilities primarily depend on Demand aggregators in identifying loads that are capable of flexible operation. Consumers can enroll their loads for DD operation and will benefit with incentives. The communication infrastructure offered by smart grid along with Internet of Things (IoT) will aid in direct control of such loads. Flexible loads such as Electric Vehicle (EV), battery storage units, water pumps, room heaters, HVAC, adaptive lighting systems etc. are few examples of such loads. The charging and discharging of EVs and battery storage systems could be controlled to have flexible demand in the grid. It is not necessary for water heaters, room heaters and HVAC units to be switched off completely; instead their consumption could be varied (reduced/ increased) moderately. In case of DD large number of such loads are aggregated and precisely controlled in real-time without sacrificing the comfort needs of consumers. The DD strategy proposed here assumes that utility have identified and prioritized such loads.

A DC microgrid consisting of a m-WTG is considered for the study. The m-WTG, installed in the roof top Renewable Energy laboratory of Amrita School of Engineering, Coimbatore, has a power rating of 100W at a wind speed of 10m/s. The microgrid is to operate in islanded mode, delivering power to the local loads. It has a battery support to serve DC loads at a nominal voltage of 12 V. DC microgrid is given in Figure 1.

The task assigned to DD here is to regulate the voltage of the DC microgrid within permissible limits. + 7.5% and – 5% have been assumed as the maximum permissible voltage regulation; it means a range from 11.4 V to 12.9 V, represented as V_l and V_h respectively. Implementation of DD requires real time synchronized measurements on the microgrid. Real Time Data Collection Unit (RTDCU) [19] developed in this laboratory is custom made for measurements on microgrids. The RTDCU is capable of simultaneously sampling DC voltage, current and then computes power consumption. The RTDCUs are time synchronized with the help of a common triggering pulse and these monitor the m-WTG generation, bus voltage, local demand and change in demand during DD. RTDCUs are equipped with ZigBee to communicate these measurements to a centralized processing unit where decisions are taken. Figure 2 depicts the DD strategy on DC microgrid and Figure 3. shows the RTDCU developed. The regular demand on the microgrid is 20W.
Each DL is connected to the microgrid through a Load Control Unit (LCU). The LCU is equipped with a ZigBee transceiver and a microcontroller to interpret the data and control signals. LCU is capable of power measurement as well. The schematic of LCU is given in Figure 4.

**DD Deployment and Performance**

The grid voltage and wind power injection are monitored in real time and DLs are controlled to regulate the grid voltage. The priority of DLs are pre-assigned for the task. A total of 8 DLs are considered for the implementation of DD on the DC microgrid. The power rating of DLs varies from 1W to 5W. The technical specifications of the m-WTG are given in Appendix. Table 1. presents the priority of DLs. The DD algorithm is depicted in Figure 5.

![Flow chart of DD](image)

**Table 1. Priority assignment of DLs.**

<table>
<thead>
<tr>
<th>S.No</th>
<th>Power rating (W)</th>
<th>Priority assigned</th>
</tr>
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<tbody>
<tr>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
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<td>7</td>
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</tr>
<tr>
<td>8</td>
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<td>3</td>
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</table>

The varying wind speed measured and recorded at the site chosen for the study (Amrita campus, Coimbatore) is presented in Figure 5. The test period is a little more than 90 minutes. The variation in wind reflected in power injection by the m-WTG and that led to voltage fluctuation in the DC microgrid. Figure 6. depicts these voltage fluctuations during the same period of test. As seen, there are violations of voltage constraint at many instants during the period of observation.

DD has then been deployed to alleviate the voltage fluctuation in the microgrid. Load addition/removal during DD operation is depicted in Figure 7 shows the record of power consumption on the microgrid; the consumption is matched to the real time generation by connection and disconnection of deferrable loads as...
decided by the DD algorithm and implemented through LCU. The rise in Figure 7 is the addition of DLs and fall is the removal of DLs. The profile of grid voltage with DD is shown in Figure 8; obviously, the voltage is maintained within the permissible range.

Conclusion

The operational constraints of a conventional power system to accommodate high RE penetration can be mitigated to a large extent in the smart grid environment. A DD scheme can be viewed as a case where DSM is directly linked with distributed generation and executed in real time using smart grid communication systems. The DD scheme proposed here continuously monitors the amount of power injected by wind and DLs are individually connected or disconnected such that the total power consumption by all connected DLs matches the power injection by the wind in real time.

Advanced Metering Infrastructure (AMI) together with Wide Area Measurement System (WAMS) offers the communication backbone needed for DD operations [18].

The Smart Meter (SM) at consumer premises will act as a gateway for DD and the associated LCU will connect or disconnect individual loads upon request.
from utility.

**Appendix**

1. micro Wind Turbine Generator (m-WTG)
   PMSG-100W, 24V, Cut-in wind speed - 3m/s

**References**


![Bus Voltage maintained below 12.9 V](image)

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