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Integration and Distribution of Renewable Sources in DC Micro Grid With Energy Storage System

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ABSTRACT--This Paper presents a dynamic modelling of a DC Micro grid which has an Solar and Wind as an Distributed Energy Sources (DES).A Multi Port DC –DC converter is used to integrate the renewable sources to the DC bus. A Direct Driven Permanent Magnet Synchronous Generator is used with a variable speed control technique so that it can extract high wind energy below the rated speed of the wind. The both solar and wind changes according to the load requirement and also the availability. An Energy Storage Element such as Battery is also integrated with the DC bus so that it can store energy when present in excess.

INDEX TERMS – DC Micro grid, Photovoltaic power systems, power conversions , wind power generations.

I-INTRODUCTION

DC Distributed energy system (DES) has the advantage to interact with Renewable Energy source due to simplicity and efficiency. Distributed energy resources include PV and fuel cell, which generates DC voltage and wind turbine and internal combustion engine which produces AC voltage. All of these resources have to be and it is cost effective. The converter consists of a Bi – Directional port for the batteries so that it can charge and discharge randomly.

II-PROPOSED MICROGRID ARCHITECTURE

Fig. 1 shows the overall architecture of the proposed Micro grid with wind and PV sources [1]. The main sources, of wind and solar radiation are converted into interfaced with a DC bus and feed power to the load, therefore dc-dc or ac-dc converters are used. The Bus can balance the voltage between the energy storage system and the DC load. Power Electronics Converter is used to interface the load and the Renewable Source. A common DC Bus is shared between the loads and to store the energy.

The conventional electrical system in place today sees our electrical devices powered by AC mains. But as renewable technologies such as solar photovoltaic and wind power become more prevalent at a household level, DC Micro grid could be a cheaper and more efficient alternative.

DC-DC converters are essential in DC Distribution Systems since they connect not only Dc sources but also DC energy storage Elements.This Paper focus on developing a DC bus for a Distributed PV and Wind Applications.

In this system the energy sources are Solar and Wind for a Distributed Energy system, and energy storage elements such as Batteries. In this system a Multi port DC converter is used such that it can interface PV and Wind with their respective MPPT to the DC bus and also to the battery. By using such kind of converters the efficiency of the DES is increased

electrical energy by wind generator and the array of PV modules. To combine these input sources a Multiport DC Converter is used. Multiport DC Converter is used because it has effective MPP tracking in PV System and effective control of input current in grid connection system. They provide a cost effective and flexible method to interface many such Renewable sources since they have multiple ports [3].

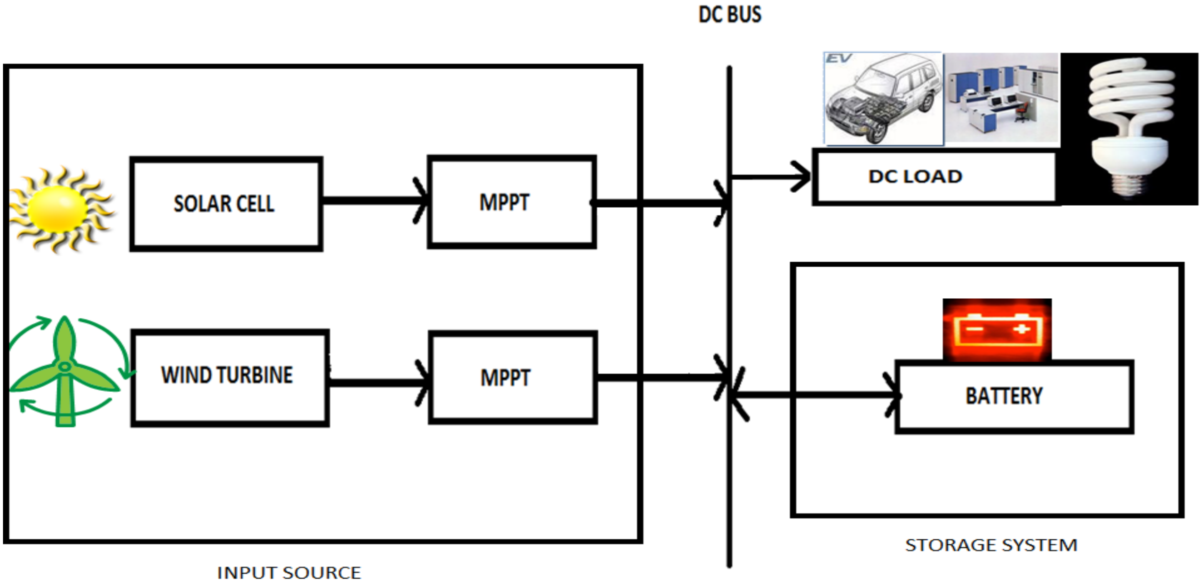

Fig:1 overall architecture of the proposed Micro grid system

In addition, DC system is used because it is present in abundant and efficiency is higher than the AC system. An Energy Storage System (ESS) is also connected to main DC bus in order to support the local loads for the uninterrupted power supply.

Depending upon applications the local loads requires different voltage levels which is obtained by the using DC – DC converters. The Converter either buck or boost the voltage obtained from the DC bus and it is given as an input to the load.

III. MODELLING OF PROPOSED MICROGRID

Modelling of various components of proposed system are as follows.

A. *PV Model*

The study of PV modelling is proposed in Fig. 2 [4].

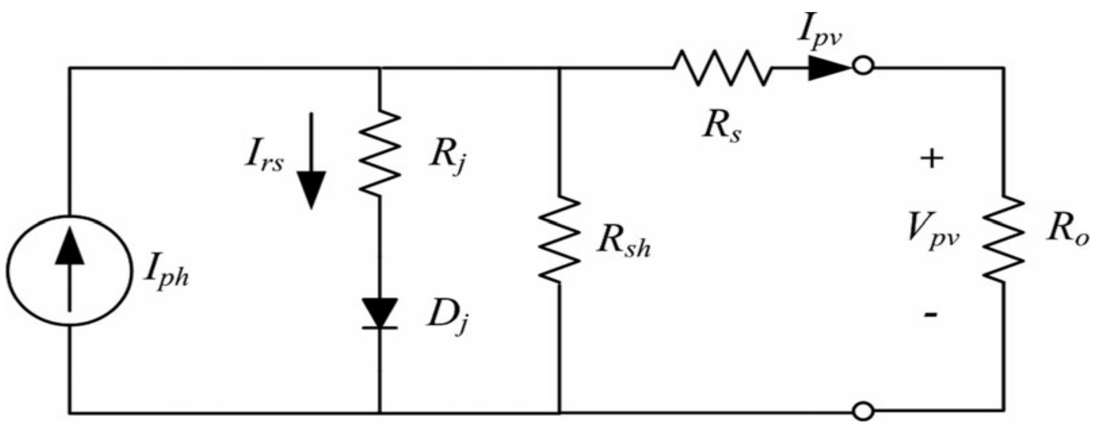

Fig. 2 : solar panel equivalent circuit

The parameters required by the PV module are number of PV modules, PV array open circuit voltage (V_{oc}), Short Circuit Current (I_{sc}) [4]. The input Parameters of the PV module is an Solar irradiance. It gives an Variation in temperature which is common in day time. The solar irradiance value given here is 1 kW / m^2.

Solar Panel current equation can be expressed by (1)-(3)

$$I_{pv} = n_p I_{ph} - n_p \left[I_{rs} exp\left(\frac{q}{kTA} \frac{V_{pv}}{n_s} \right) - 1 \right] (1)$$

Where V_{pv} is output voltage of solar panels, I_{pv} is output current of solar panels, n_s is number of solar panels in series , n_p is number of solar panels in parallel, k is the Boltzmann constant(1.38 × 10- 2 3 J/K), q is electron charge (1.6 × 10-1 9 C), A isidealityfactor (1–2), T is surface temperature of the solar panels(K), and Irs is reverse saturation current.

$$I_{rs} = I_{rr} \left[\frac{T}{T_r} \right] exp\left(\frac{qE_g}{kA} \left(\frac{1}{T_r} - \frac{1}{T} \right) \right) (2)$$

T_r is the reference temperature of solar panel.I_{rr} is reverse saturation current of solar panel at temperature T_r and E_g is energy band gap of semiconductor material.

$$I_{ph} = [I_{scr} + \propto (T - T_r)] \frac{S}{100} (3)$$

Where I_{scr} is the short circuit current at reference temperatureT_r and illumination intensity 1 kW/m^2,$\propto$ is the short circuit current temperature coefficient and S is the illumination intensity.

B. Wind Turbine Modelling

Wind Turbine operated in standalone system is very important and popular renewable energy. A Permanent Magnet Synchronous Generator (PMSG) based variable speed wind turbine (VSWT) is gathering much attention because of simplicity, less maintenance, high efficiency and high power factor operation [2].

The wind generator used here is Direct Driven PMSG, which is gearless. It doesn't require frequent maintenance because they don't have any gear system connected between wind blades and the generator. It also eliminates the DC link excitation circuit thus reducing its complications.

In order to simulate the spatial effects of wind energy variations such as gusting, change in voltage and the back ground noise, the wind model is defined by

$$V_{wind} = V_{base} + V_{gust} + V_{ramp} + V_{noise} (1)$$

V_{wind} is the wind velocity, V_{base} is the constant wind velocity, V_{gust} is the gust wind components which can beimplemented by cosine function, V_{ramp} is the components which is used during rapid changes, and V_{noise} is the background noise of the wind.Fig.3. shows the wind model used for study for simulation.

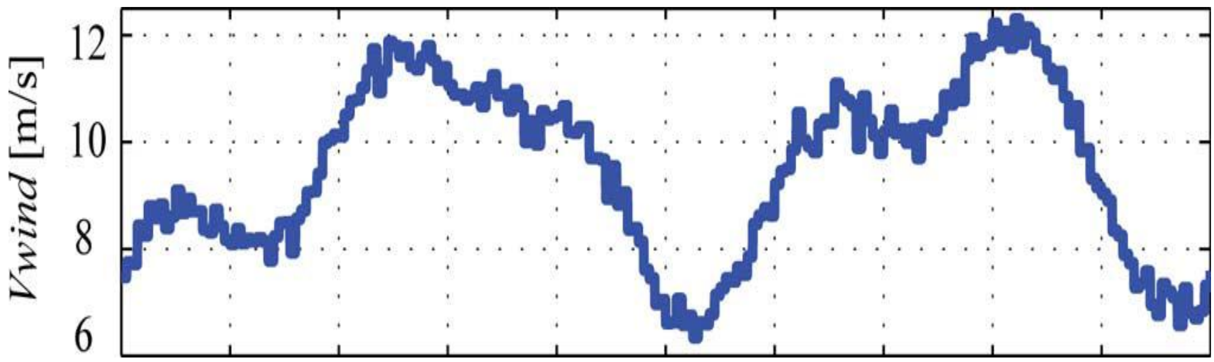

Fig. 3. Wind model used for the simulation study.

A wind turbine in the proposed Microgrid application is modelled by an aerodynamic input torque which drives a wind generator. The mechanical power(P_m) captured by blades of a wind turbine is given as[7]:

$$P_m = \frac{1}{2} C_p(\beta, \lambda) \rho \pi R^2 V_{wind}^3 \quad (2)$$

Where C_p is a rotor power coefficient , β is blade pitch angle, λ is a tip speed ratio, ρ is air density, R is radius of wind turbine blade and V_{wind} is the wind speed. The rotor power coefficient is defined by the fraction of available wind power that can be transformed to mechanical power rotor [8]. C_p depends on the blade aerodynamics, which is the function of β and λ [9],[7]. The type of a wind turbine rotor may also be another factor affecting the C_p. However ,C_p [7] in which a general blade type was assumed is used in this simulation for simplicity[9].

$$C_p = (0.44 - 0.0167\beta) sin \frac{\pi(\lambda - 2)}{13 - 0.3\beta} - 0.00184(\lambda - 2)\beta \quad (3)$$

The TSR (λ) can be defined as the function of a wind speeds [9], [7],

$$\lambda = \frac{\omega_m R}{V_{wind}} \quad (4)$$

Where ω_m is the rotor speed of a wind turbine. Then from (2) and (4) and considering that $T_m = {}^{P_m}/_{\omega_m}$, the aerodynamics input torque T_m by which a wind generator is driven can be obtained [9].

C.DC-DC Converter Modelling

Fig. 3 shows the proposed integrated three-port dc–dc converter topology. A three-phase DAB converter is applied to realize the bidirectional power flow function and the Y-Y connected high-frequency transformers can provide galvanic isolation and voltage-level matching between low voltage energy sources and high-voltage dc bus [5]. The leakage inductances Ls1 − Ls3 of the transformer are used as energy storage elements to transfer the power between two sides, and the power flow is mainly controlled by a phase-shift angle ϕ. The middle points of three legs in the LVS are connected to one energy source port through three dc inductors Ldc1 − Ldc3, and duty cycle D is another control variable to adjust the power distribution between the two ports of the LVS. In the application of a PV system on dc distribution bus, the converter is applied to interface with PV panels, BU, and dc bus or load. The BU is connected to the LVS dc link. The voltage of the battery changes slowly with different SOCs, so the primary-side dc-link voltage can be treated as almost constant. The PV panels are connected to the current source port. The output voltage and current of PV change in a large range due to different solar irradiation and ambient temperature. Three-phase dc inductors and primary-side switches are used to boost the PV voltage and MPPT can be realized by the duty cycle control. With the help of dc inductors, the ZVS is guaranteed in all the operation modes, even though the battery's voltage changes with different SOCs. Compared to the single phase topology, the three-phase interleaved topology can reduce the current and voltage ripples to reduce the inductor and capacitor's size.

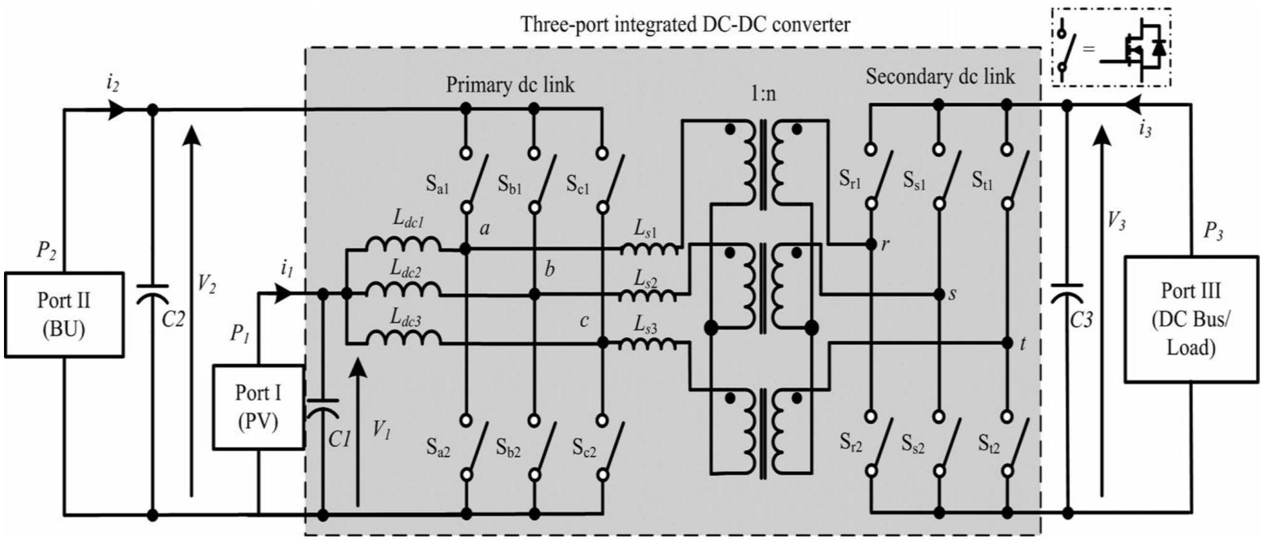

Fig. 3. Proposed three-port integrated bidirectional dc–dc converter.

The control unit of converter has an MPPT algorithm. The MPPT can be realised by controlling the duty cycle D. There are 12 switching frequency system. Fig 5.Shows the control unit of converter.

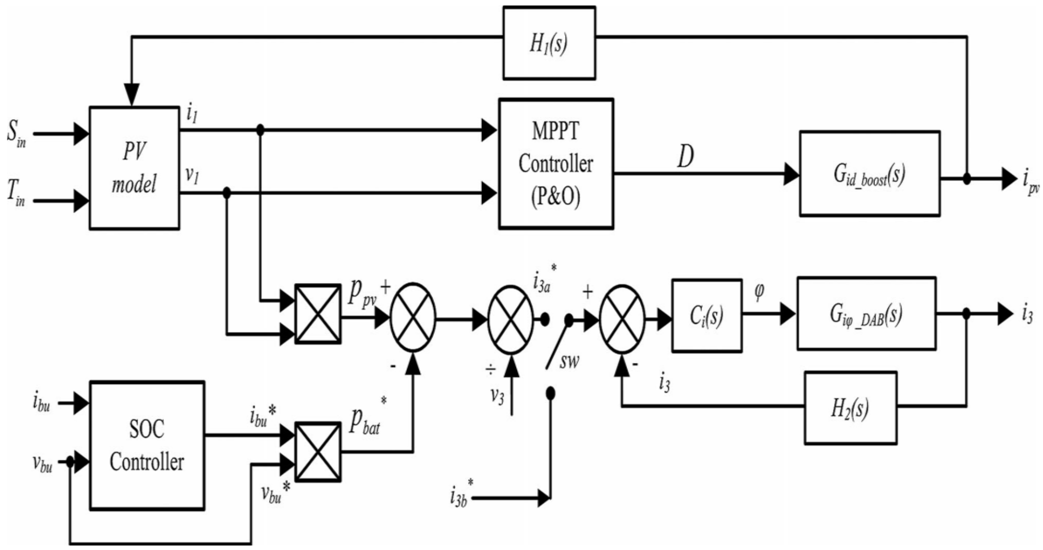

Fig. 5. Control system diagram

D.Energy Storage System

This study considers batteries as energy storage devices.However, these batteries may require a dc-dc power converterin order to step up their voltage (V_{batt})to the main dc busvoltage (V_{DC})because their nominal voltage whose level is 240V in this microgrid is typically lower than the main dc busvoltage [6].

One reason for using a lower battery voltage is to improvetheir reliability and life-time by avoiding issues found in higher voltage configurations, such as cell voltage equalization.For this purpose, a bidirectional boost/buck converter shown in Fig. 6.is considered in the proposed microgrid. If the powergeneration from the renewable micro-energy sources is insufficientfor the demand power at the load side, this bidirectional converter operates in a boost mode in order to discharge energyfrom batteries to the main dc bus as depicted in Fig. 6. But,when the renewable power production exceeds the load-sidedemand power, this power converter works in a buck mode inwhich power flows from the main dc bus to charge the batterieswith the extra local power production.

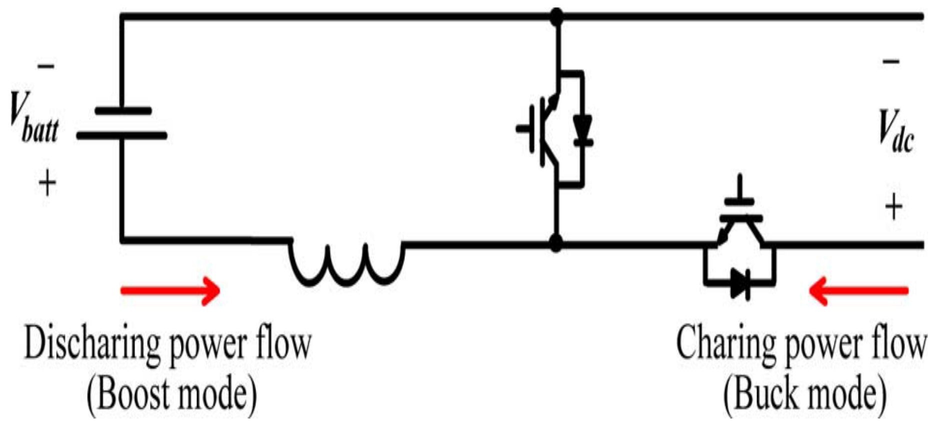

Fig. 6: energy storage system

The Energy storage system in the Microgrid is controlled to regulate the main dc bus voltage (V_{dc}) both when there is not sufficient power production in PV as well as Wind and when there is excess power production in order to charge the battery. A bidirectional buck- boost converter is shown in Fig.6. is used to charge and discharge the battery with the hysteresis control in [10]. If V_{dc} is higher than a upper voltage limit say 390V, then battery will be charged in buck mode. If V_{dc} is lower than lower voltage limit say 370V, then battery will be charged in boost mode. If not within in limit then it will be in float mode.

IV CONCLUSION

This paper presents the modelling of DC Microgrid with solar and wind as their input source. These renewable sources are integrated into the main DC bus through bi directional dc-dc converter. Wind energy variation and rapidly change in solar irradiance were considered in order to explore the effect of such environment variations to the proposed Microgrid. In addition the proposed Microgrid is equipped with energy storage system and its connected to distributed system. These micro energy resource can improve the Microgrid efficiency and reduce variations in the input system. The is also cost effective and smaller in size.

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