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IMPACT OF BATTERY ENERGY STORAGE SYSTEMS ON HARMONICS IN HYBRID MICROGRID

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ABSTRACT

RenewableEnergy Resources are intermittent in nature and hence Energy Storage System(ESS) with bidirectional flow capability can be incorporated to the Microgrid to smoothen the load profile. The main objective of the paper is to perform an analysis of the Microgrid with a hybrid combination of Photovoltaic, Wind and Battery Storage and to study the impact of harmonics on the above system with variation in generation.The configuration is tested using MATLAB/ SIMULINK platform and it is seen that the change in generation is compensated by the battery management system at the point of common couplingand hence harmonics is reduced for the system when battery is connected.

KEYWORD: Battery, Energy Management System, Hybrid Microgrid, Wind, Photovoltaic (PV)

I. INTRODUCTION :

FREQUENCIES other than fundamental frequency produced by certain types of loads which causes change in output voltage and current are considered as electrical pollution and are termed power system harmonics. Power Electronic Loads that use power transistors, diodes, SMPS etc. to convert power from AC to DC or to control power, produces harmonics since they draw current only during certain intervals of the cycle and they are no longer sinusoidal in nature which produces voltage distortion. Due to increasing energy demands, Renewable Energy Sources such as PV are integrated into the low voltage distribution grid with Pulse Width Modulation Techniques [1] and Voltage Source Inverters which produces power quality disturbances and utility grid harmonics.Measures are taken to adopt new methods for interconnecting wind generators into the microgridsand their performances are studied in detail in [2]. Storage devices such as Battery are also incorporated into the Microgrid to compensate the slow response of the sources and unavailability[3]. These renewable Energy Sources combined with local loads and controllers form a Microgridand are connected to the main grid at a point called Point of Common Coupling (PCC). The distribution of harmonic current in hybrid Microgrid are analyzedwith their causes and methods of improvement are discussed in [4].

The power Quality of hybrid microgrid during grid connected and islanded operation are studied in [5] and it is found that under isolated condition THD is more when compared with grid connected system. Energy storage is used as power quality compensator for microgrid in [6].The above literatures fail to explain the impact of power quality in microgrid when the generation varies. This paper presents an analysis of the impact of harmonicson Hybrid Microgrid during changes in generation.

II. SYSTEM CONFIGURATION :

The block diagram of Hybrid Microgrid is shown in Fig.1. which consists of PV, Wind, Battery and Utility grid.

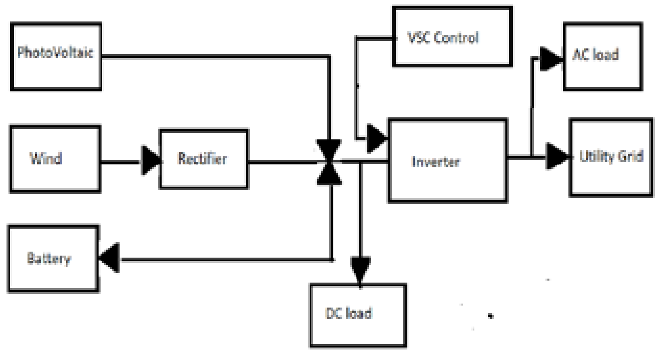

Fig 1 Block diagram of hybrid microgrid with PV and DFIG

MATHEMATICAL MODELING OF PV

A PV Cell is a p-n junction diode which converts sunlight into electrical energy.The circuit diagram of a PV cell is shown in Fig.2, which contains a diode, with series and shunt resistances [7].

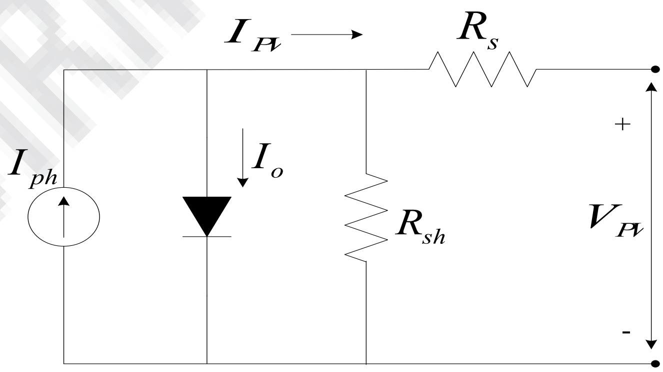

Fig 2 : Equivalent circuit of PV

The diode current (I_O) can be written as shown in equation (1),

$$I_O = I_S[\exp[\alpha(V_{PV} + R_S I_{PV})] - 1] \quad (1)$$

The output current of the PV generator (I_{PV}) can be written as equation (2),

$$I_{PV} = I_{ph} - I_S[\exp[\alpha(V_{PV} + R_S I_{PV})] - 1] - \frac{V_{PV} + R_s I_{PV}}{R_{sh}} \quad (2)$$

Here constant $(\alpha) = q/AkT_c$

(where $k = 1.3807 \times 10^{-23}$ J/K and $q = 1.6022 \times 10^{-19}$ C).

MATHEMATICAL MODELING OF WIND

In this method, the pattern arrangement of a variable speed wind turbine is employed, which is shown in Fig.3. The output power (P_W) of the wind turbine is determined by equation (3),

$$P_W = 0.5\rho A C_p(\lambda,\beta)V_W^3 \quad (3)$$

Here, ρ is air density, A is rotor swept region, V_W is wind speed and $C_p(\lambda,\beta)$ is the power coefficient which is the tip speed proportion to λ and pitch angle β. The arithmetical representation of a DFIG [8] with the excitingequation is specified in equations (4) and (5),

$$\frac{J}{n_p}\frac{dw_r}{dt} = T_m - T_{em} \quad (4)$$

$$T_{em} = n_p L_m (i_{qs} i_{dr} - i_{ds} i_{qr}) \quad (5)$$

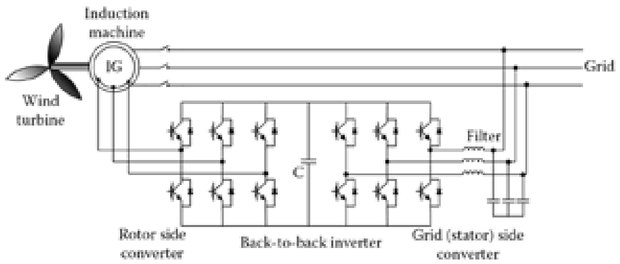

Fig.3: Equivalent Circuit of Wind Energy Conversion System

At this point, the subscripts d, q, r and s are d-axis, q-axis, rotor and stator correspondingly, L is the inductance, λ is the flux linkage, u and i are voltage and current correspondingly, w_1 and w_2 are the angular synchronous speed and slip speed correspondingly, $w_2 = w_1 - w_r$, T_m is the automatic torque, T_{em} is the electromagnetic torque [9]

ENERGY STORAGE SYSTEM (ESS)

The ESS contains a lead acid battery and a bidirectional DC-DC buck-boost converter which is associated to the DC-link of the Microgrid. The purpose of this converter is to preserve the DC-link voltage constant with the power changes in the resources and the load. The battery storage system is used to observe the charging, discharging and estimate the state-of-charge (SOC) of the battery. Suppose, if the renewable energy system(RES)has sufficient power to the meet the load requirement, then this battery will turn offand the RESdelivers the required energy to the load. If there is a power deficiency from the renewable energy generation systems, then the battery bank is released to supply the load requirement.

The state of charge (SOC_{bat}) of batteryis modelled as equation (6),

$$SOC_{bat} = 100\left[1 - \left(\frac{1}{Q_{bat}}\int_0^t i_{bat}(t)dt\right)\right] \quad (6)$$

Where, Q_{bat} is the battery capacity (Ah) and i_{bat} is the battery current. In this MG, the controller manages the charging and discharging of the batteries [10]. The SOC of the battery is restricted to a least amount of 20% and a greatest of 100% in its Ampere-hour capacity and this is done to avoid the undercharging and overcharging of the battery bank therebyextending its life. The battery charging limitations are specified in equation (9),

$$SOC_{min} \le SOC(t) \le SOC_{max} \quad (7)$$

The battery charging and discharging limitations are specified in equation (8),

$$P_C, P_D \le \frac{0.1 V_{bat} Q_{bat}}{\Delta t} \quad (8)$$

Where, P_C is the charge power (kW) and P_D is free power (kW), V_{bat} is the voltage at the battery AC link and Δt is the time step (seconds). In this document, an intellectual power organization control of a combined Wind/Photovoltaic system among battery storage is offered.The power balance is achieved by the following balance equation (8)

$$P_W + P_{PV} - P_{LOSS} = P_{LOAD} + P_{BAT} \quad (9)$$

Where, P_{BAT} is the battery power and

P_{PV} is the output power of PV

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P_W is the output power of Wind and

P_{LOSS} is the total power loss in the MG.

Harmonic Distortion in Microgrid

Non linear devices where current is not proportional to applied voltage produces harmonic distortion. Analysis of harmonics must be done since critical loads such as sensitive computers are connected to microgrids. The ratio of total harmonic component to fundamental component is Total Harmonic Distortion (THD).

$$THD = \frac{\left(\sum_{n=2}^{k} U_n^2\right)^{\frac{1}{2}}}{U_1} x100\% \quad (10)$$

Where U_n – harmonic component

U_1 – Fundamental component

K – observed maximumharmonic component

III. RESULTS AND DISCUSSION :

Energy storage protect the sensitive loads against voltage dips and imbalance which enables compensation of current harmonics in microgrid[6] thereby shielding the utility grid from harmonicsbut filtering is needed for nonlinear loads. The SIMULINK block diagram of hybrid microgrid developed is shown in Fig. 4

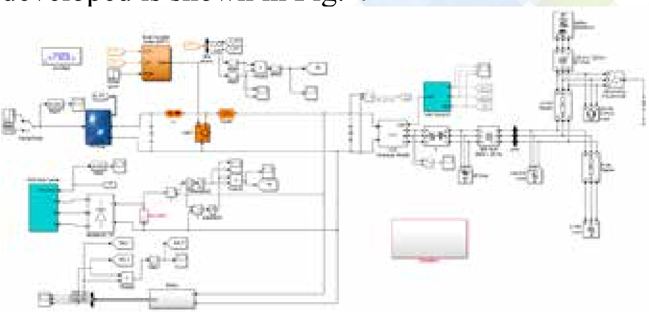

Fig.4 : Simulink diagram of hybrid microgrid

This Simulation study is organized as two different cases (i) Battery connected to microgrid and (ii) Battery disconnected from Microgrid.

Case (i) Battery Energy Source disconnected from microgrid

This analysis shows the battery disconnected from Microgrid but renewable energy sources, Wind and PV are still connected to the system. This situation is tested for variable wind and constant wind speed of 15 m/s from Wind converter as shown in Fig.5 and Fig.6. It is seen from Fig.7 and Fig. 8 that the THD is 4.60 for variable wind system and 4.29 for constant wind speed.

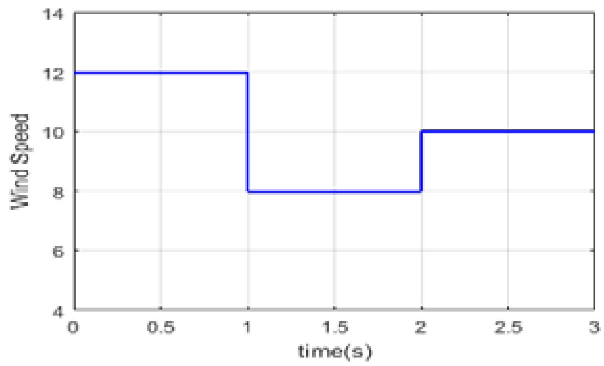

Fig.5Variable wind speed

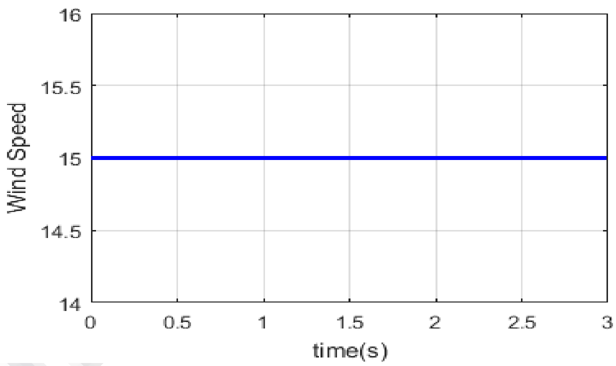

Fig.6 Constant wind speed

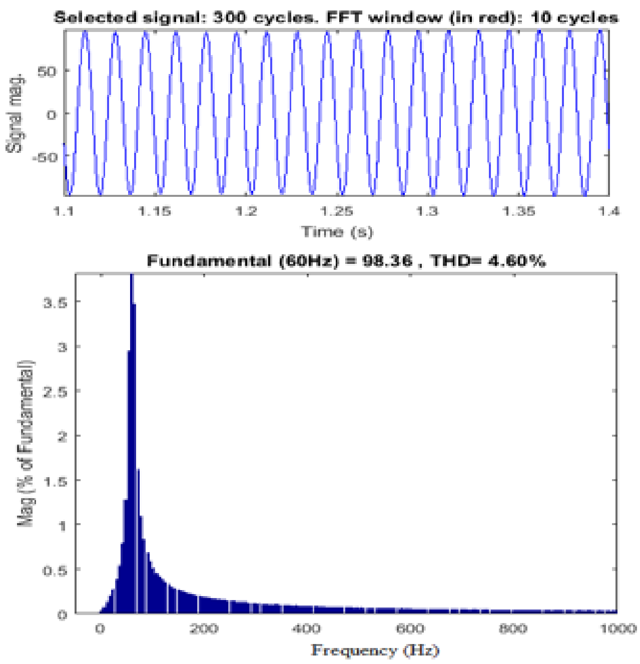

Fig.7 THD analysis for the system without battery and variable wind speed

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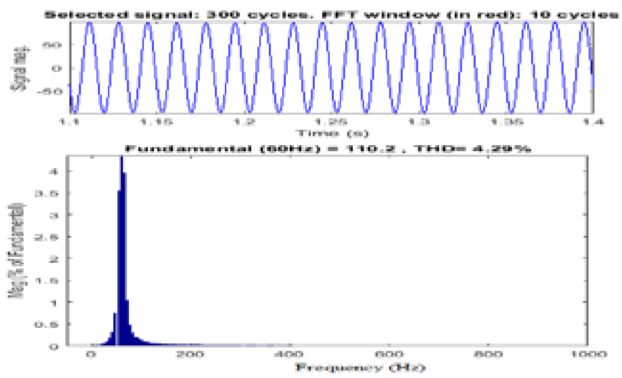

Fig.8 THD analysis for the system without battery and constant wind speed.

Case (ii) Battery Energy Source Connected to microgrid

The analysis is again repeated with battery connected to the microgrid and tested for variable and constant generation. It is seen that the THD has reduced significantly to 2.93% for system with variable wind speed and 2.11% for constant wind speed, since battery acts as a compensator for keeping the DC link voltage constant and thereby injecting almost constant current to the inverter and is shown in Fig. 9 and Fig.10.

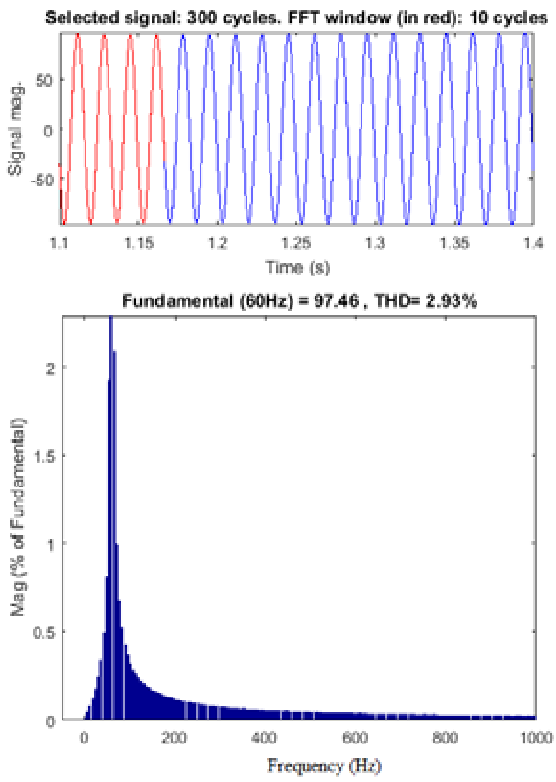

Fig.9 THD analysis for the system with battery and variable wind speed.

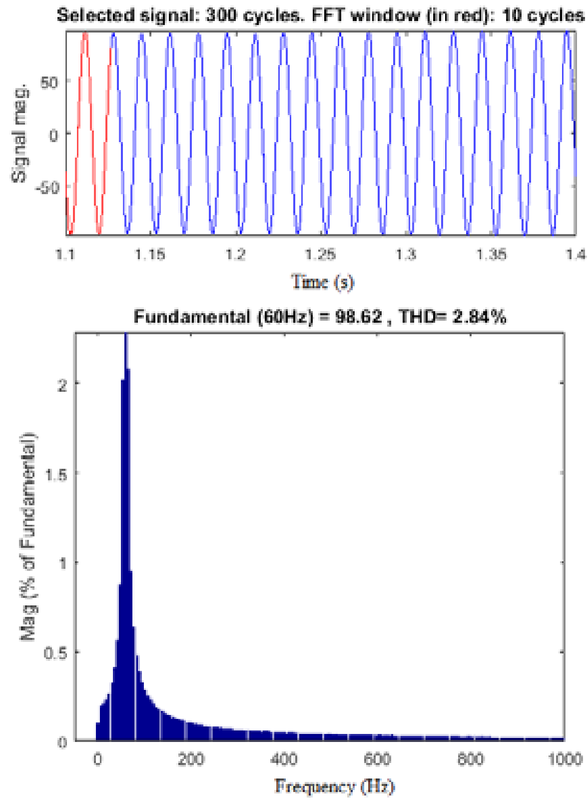

Fig.10 THD analysis for the system with battery and constant wind speed.

IV. CONCLUSION:

In this paper, an analysis of hybrid Microgrid with PV, wind and battery storage is done for change in generation, with and without battery.From the results,it is seen thatpower variation from PV and Wind causes corresponding variation in the power quality and battery acts as a compensator and supplies power to smoothen load profile in addition to improving the harmonics created by the influence of DC component present in the AC output of Wind generator.

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