Grid Connected PV-Wind Energy System for Luxmanda Village in Tanzania

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Abstract: There are rural areas in Tanzania which still lack access to the national grid. One of such locations is Luxmanda village in Manyara region. This village gets its power from islanded renewable energies microgrid (MG) which is able to supply about 25.4 kW. However, this is way below the projected consumption. Therefore, this paper proposes connecting the islanded MG to the grid to supply enough power to the village for prosperity. The paper discusses the solar photovoltaic generation, wind generation and the DC grid. Steady state operating of the MG is established at 750 V DC.

I. Introduction

Globally, the hybrid renewable energies systems (HRES) are supplying about 181 GW thanks to technological advances which enable efficient energy conversion (Alkahtani et al., 2020) and for the case of solar photovoltaic (PV). Tanzania has the potential to generate appreciable electricity from solar PV, even in cases of cell shading (Justo and Mushi, 2020). However, many parts of Tanzania still lack electricity, whether grid connected or from local microgrid sources. One area of Tanzania afflicted with energy deficiency is the village of Luxmanda, found in Manyara region. This village has an isolated (islanded) microgrid made up of HRES that supplies some of her loads.

Therefore, this paper proposes connecting this village's HRES to the grid, anticipating that the proposed system might work in grid connected mode or if there is grid failure in islanding mode. There are challenges of connecting HRES to the grid due their nature of intermittency, and unpredictability – that they cause technical challenges to weak or standalone grids with small storage (Bevrani and Shokoohi, 2013). These challenges limit higher penetration of HRES to the grid. The Luxmanda village HRES is proposed to be optimally deployed to reliably supply energy to the consumers.

II. Methods and Materials

A) Description of the Study Site

Luxmanda village with a population of 3208 is located in Tanzania, Manyara region, in Babati district at Ufana ward. This village currently uses renewable energies system (RES), that is solar photovoltaic (PV) and wind energy conversion (WEC) systems which is 25.4 kW. Respectively the solar PV gives 20.4 kW and WEC gives 5 kW. This hybrid RES (HRES) is connected to the DC bus at 750 V. There is the main grid, which up to now does not supply power to the village, thereby denying wider supply of electricity to the village. The HRES supplies the village hospital, school, Village Chair Office and few other villagers. The existing HRES currently works in islanded mode, because the grid is not connected to Luxmanda village.

B) Modeling the Luxmanda Solar Photovoltaic Plant

The Luxmanda village solar PV plant is made up of 10 series and 66 parallel panels totaling 25.4 kW. These are used to convert the incident solar power into electricity (Amir et al., 2019; Samir et al., 2018). The solar PV panel is made of several modules. Figure 1 show the solar PV which has a photon current source I_{ph} in parallel to ideal diode passing current I_d shunt resistor R_p, and with series resistor R_s. This combination gives output I_{PV} and V_{PV} as current and voltage respectively. The output current is computed by (1), where the electric charge is $q = 1.60217646 \times 10^{-19}$ C; the Boltzamann constant is $k = 1.3806503 \times 10^{-23}$ J/K; I_0 is the diode reverse saturation current; thermal voltage is V; and the T represents the temperature of the cell.

$$I_{PV} = I_{ph} - I_0\left(e^{\frac{qV}{kT}} - 1\right) \equiv I_{ph} - I_d \quad (1)$$

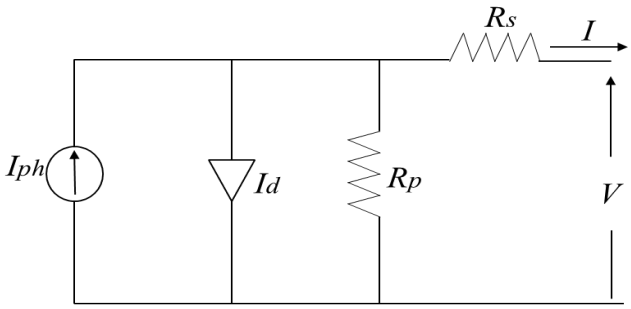


Figure 1: Single diode model of PV cell (Samir et al., 2018)

C) Modeling the Luxmanda Wind Energy Conversion Plant

The Luxmanda WECS consists of two variable speed wind turbine type, permanent magnet generator (PMSG) type. The steady state power P_w produced by the wind turbine is given by Sahu et al. (2018) in (2), where C_p is the power coefficient, λ is the tip speed ratio of the rotor blade tip to wind speed, β is the blade pitch angle (degree), ρ is the air density, A is the area swept by the blades, and V_w is the wind speed (Lertnuwat and Oonsivilai, 2017).

$$P_w = \frac{1}{2} C_p(\lambda, \beta)\rho A V_w^3 \quad (2)$$

This wind turbine is connected to a permanent synchronous generator (PMSG) with parameters shown by Table 1.

TABLE 1: Parameters of Luxmand village PMSG

Parameter	Value	Units
Rated power	5.0	kW
Rated speed	90.0	rad/sec
Rated current	8.0	A
Armature resistance	1.95	Ω
Magnet flux linkage	0.43	wb
Stator inductance	1.9	mH

Source: Sahu et al., 2018

D) Modeling the Luxmanda DC-DC Converters

The solar PV generates unregulated DC power, which cannot be directly applied to the Luxmanda DC bus. Therefore, a DC-DC boost converter whose equivalent circuit is shown by Figure 6(a) is needed to regulate and step up the V_{PV} reach the DC bus voltage, V_{dc}. Additionally, the WECS generates unregulated AC power, which is converted to unregulated DC at voltage V_{w-DC}. This power needs to regulated and step up to reach the DC bus voltage V_{DC} as shown in Figure 2. Where the input voltage V_{in} can be either V_{PV} or V_{w-DC}. The input current i_{in} can be either the solar PV current I_{PV}or the WECS DC current I_w. This converter has input inductor L, switch Q, diode, output capacitor C through which capacitor current i_C flows, output current i_{DC} with load resistor R at bus voltage V_{DC}, for which the steady state is shown by Mushi et al., (2017) in (3), where D is the steady state duty cycle. The DC-DC boost converter for this study is modeled with the parameters listed in Table 4.

$$V_{dc} = \frac{1}{1-D} V_{in} \tag{3}$$

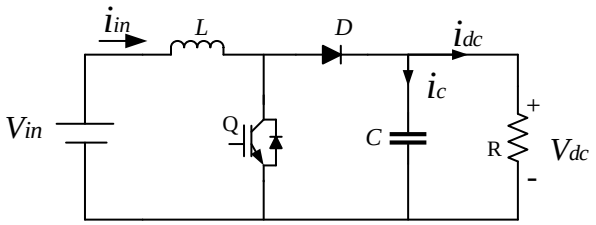


Figure 2: Circuit diagram of a boost converter

TABLE 2: The boost DC-DC converter parameters

Parameter	Value	Units
D	0.219	–
L	11.6	mH
C	50.89	µF
R	112.5	Ω

E) The Luxmanda Village HRES

The Luxmanda village gets its power from the islanded microgrid formed by interconnected components discussed in section II(A) – (E). Figure 1 shows this complete system under current study – solar PV, WECS, DC bus, DC loads and storage system. In future with the completion of this study, the following will be added – DC-AC converter to connect to the grid via point of common coupling (PCC), microgrid AC loads, and the grid via the transformer as Figure 3.

III. SIMULATION

The solar PV system in Figure 1 is simulated by using MATLAB/Simulink software to obtain the constant dc voltage as output from the boost converter for the purpose of grid connection. These results are shown by Figure 4(a) for solar PV to DC output, and Figure 4(b) for WECS to DC output.

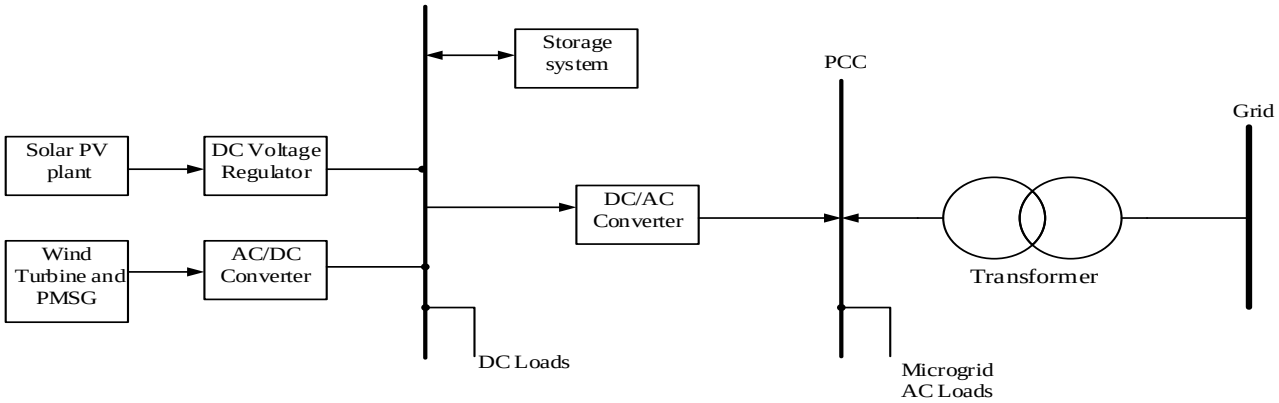


Figure 3: Overall hybrid solar PV and wind system

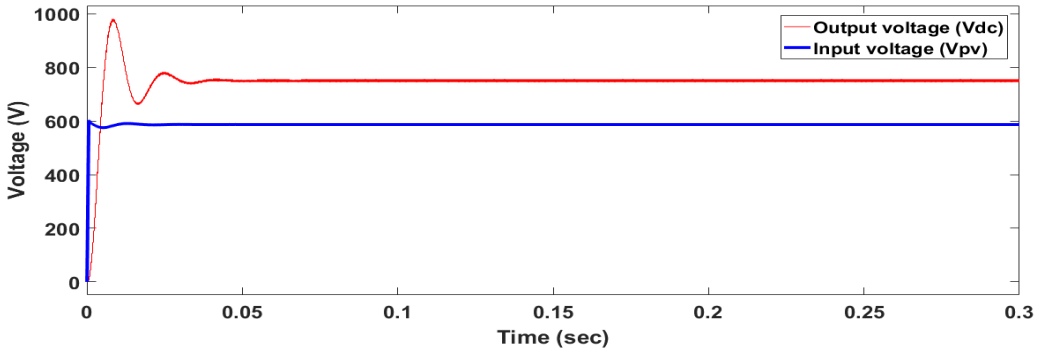


Figure 4(a): The input and output from solar PV to DC output

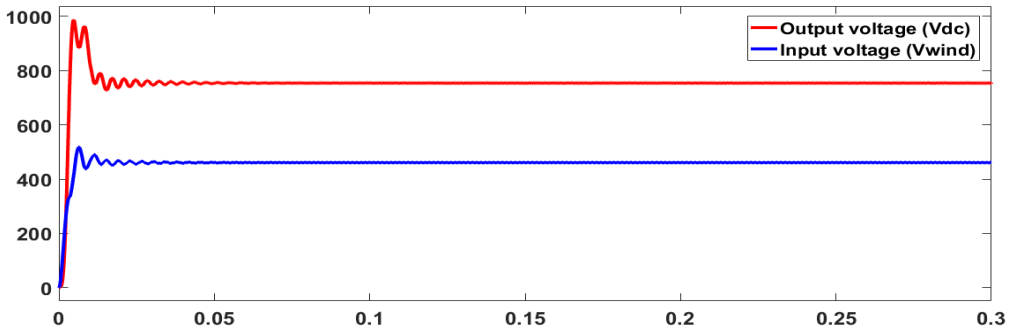


Figure 4(b): The input from WECS to DC output

IV. Conclusion

The hybrid system of solar and wind to obtain DC bus voltage for grid connection is modeled and simulated and the DC bus voltage obtained for the two system is 750 V and the future work is to connect them into grid through inverter.

V. References

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