International Journal of Research
Available at https://edupediapublications.org/journals
e-ISSN: 2348-6848
p-ISSN: 2348-795X
Volume 04 Issue14
November 2017

Hybrid PV/Fuel Cell System integrated to AC micro grid

K. R. Anugna Hinduja & V. Dhanunjaya
[1]Assistant Professor, Department of Electrical Engineering, SRTIST, Nalgonda, Telangana, INDIA
[2]Assistant Professor, Department of Electrical Engineering,BVRIT Hyderabad, Telangana, INDIA

Abstract-*Power extension of grid to isolated regions is associated with technical and economical issues. It has encouraged exploration and exploitation of decentralized power generation using renewable energy sources (RES). RES based power generation involves uncertain availability of power source round the clock. This problem has been overcome to certain extent by installing appropriate integrated energy storage unit (ESU). This project presents technical review of hybrid wind and photovoltaic (PV) generation in standalone mode. Associated components like converters, storage unit, controllers, and optimization techniques affect overall generation. Wind and PV energy are readily available, omnipresent, and expected to contribute major future energy market. It can serve to overcome global warming problem arising due to emissions in fossil fuel based thermal generation units. This project includes the study of progressive development of standalone renewable generation units based on wind and PV micro grids.*

I. INTRODUCTION

Stand-alone dc micro grids

Microgrids are new key elements of modern power grids that improve the grids capability of hosting renewable energy and distributed storage systems [1]. In fact, in the near future, distribution networks will consist of several interconnected microgrids that will locally generate, consume, and even store energy [2]. Microgrids may operate as an extension of the main grid, i.e. the grid-connected mode, or as a stand-alone network with no connection to the grid. Stand-alone sustainable microgrids have some distinct applications in avionic, automotive, or marine industries, as well as in remote rural areas. In such stand-alone microgrids, intermittent solar and wind energies coupling with battery storages contribute realistic sources to supply variable load demands [3]. However, comparing to the grid-connected microgrids, three well-known issues regarding voltage regulation, power sharing, and battery management, are more severe in stand-alone microgrids leading to the necessity of more sophisticated control strategies.

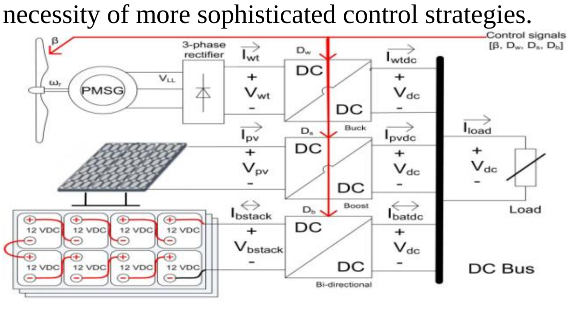


Figure 1: Topology of stand-alone green microgrids in this study

In order to model such a hybrid system, such an impact is modelled with a discrete-time state; however, height and velocity states are continuous between each two successive impacts [5].

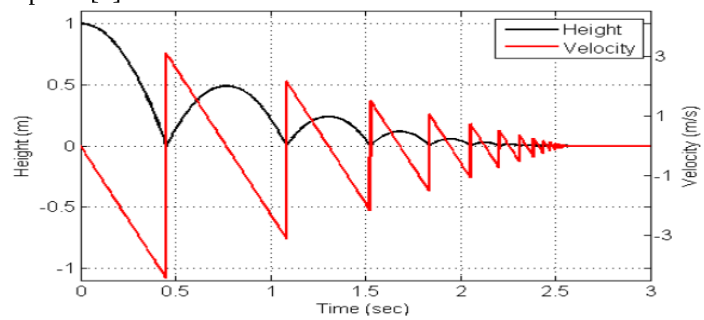


Figure 2: A bouncing ball as a hybrid dynamical system

A model of hybrid dynamical systems requires describing both continuous- and discrete-time dynamics as well as regions in which these dynamics are applied [4]. It should also take into account the interconnection between the continuous and discrete dynamics and mode transitions criteria. There are a number of approaches to model hybrid systems, including hybrid automata, differential inclusion, mixed logical dynamical systems, complementarity systems, and piecewise affine systems, to name a few.

Modeling of Stand-alone dc Microgrids as Complementarity Systems

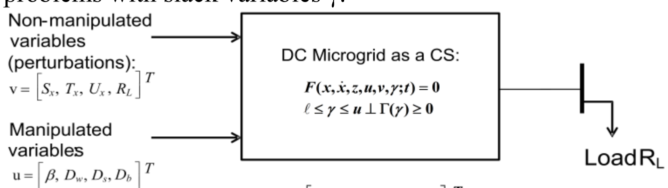
Due to bimodal operation as well as existent discontinuous differential states, batteries and therefore microgrids belong to the class of hybrid dynamical systems of non-Filippov type. In order to develop a mathematical model applicable to NMPC strategies, stand-alone dc microgrids are approximated as complementarity systems of Filippov type. The presented model is also used to develop a Modelica model for the long-term simulation purposes.

Microgrids are the building blocks of modern power grids. As explained in Chapter 1, due to some challenges that ac microgrids face with, dc microgrids get more popular particularly for stand-alone applications. There are new interests to employ NMPC technique to develop coordinated multivariable control strategies for stand-alone microgrids. However, such control strategies require using a mathematical model of microgrids to predict their behavior during the prediction horizon. Moreover, in smart grid applications, such a model is needed to simulate the microgrids behavior for at least one day ahead.

International Journal of Research
Available at https://edupediapublications.org/journals
e-ISSN: 2348-6848
p-ISSN: 2348-795X
Volume 04 Issue14
November 2017

Modeling of stand-alone dc microgrids as complementarity systems

Figure 3 summarizes the developed model for the stand-alone dc microgrid topology given in Figure 1. It can be seen that the dc microgrid is modeled as a CS including mixed complementarity problems with slack variables γ.



$$x = [I_f,\ Q_{act},\ \omega_r,\ V_{exp}]^T$$

$$z = [I_{pv}, V_{pv}, I_{pvdc}, I_{bstack}, V_{bstack}, I_{batdc}, I_{wt}, V_{wt}, I_{wtdc}, T_e, T_m, \lambda, C_p, SOC, I_{load}, V_{dc}]^T$$

$$\gamma = [\gamma_1,\ \gamma_2]^T$$

Figure 3: DC microgrids as complementarity systems

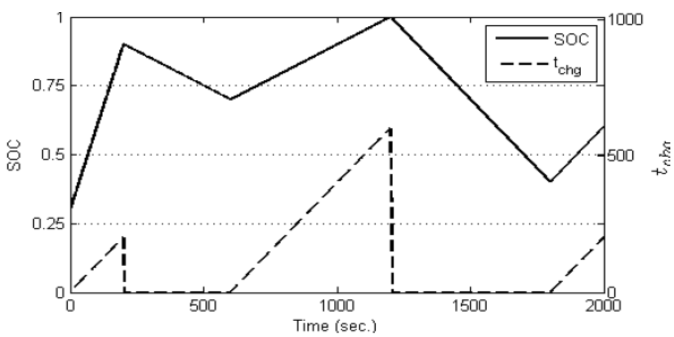


Figure 4: the introduced charging cycle, tchg, state of battery in terms of state of charge (SOC).

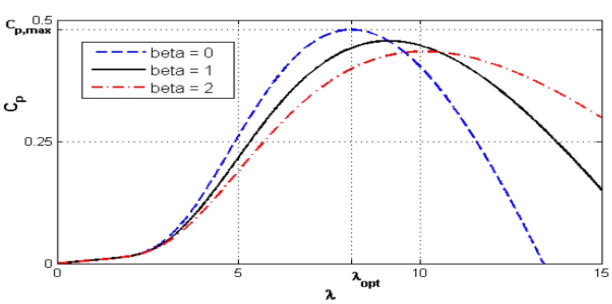


Figure 5: Power coefficient curves in terms of tip speed ratio

II. SIMULATION RESULTS

Table 1 shows the parameters of different components and their values in this study. The linear load demand is also less than or equal to 12 KW. Two test scenarios are carried out to evaluate the performance of the developed optimal EMS.

Table 1
Wind Turbine, PMSG, Battery Stack, and PV Parameters in This Study

Wind turbine		PMSG		Battery stack		PV array	
$C_1(-)$	0.517	$J(Kg.m^2)$	0.35	$C_{max}(Ah)$	48.15	$R_s(\Omega)$	0.221
$C_2(-)$	116.0	$F(N.m.s)$	0.002	$R_{bat}(\Omega)$	0.019	$R_{sh}(\Omega)$	405.4
$C_3(-)$	0.4	$P(-)$	8	$V_0(V)$	12.3024	$n_d(-)$	1.3
$C_4(-)$	5.0	$\psi(V.s)$	0.8	$P_1(-)$	0.9	$N_s(-)$	54
$C_5(-)$	21.0	$P_{rated}(KW)$	10.0	$N_{bats}(-)$	8	$I_{sc,stc}(A)$	8.21
$C_6(-)$	0.007	$L_s(H)$	0.0083	$N_{batp}(-)$	3	$V_{oc,stc}(V)$	32.9
$\lambda_{opt}(-)$	8.1			$T_s(sec)$	0.726	$k_I(A/K)$	0.003
$P_{wt,nom}(KW)$	10.0			$V_{bstack,nom}(V)$	96.0	$k_V(V/K)$	-0.12
Rad (m)	4.01			$P_{bat,nom}(KW)$	1.296	$N_{pvs}(-)$	1
$U_{x,base}(m/s)$	12.0			$C_{10}(Ah)$	45.0	$N_{pvp}(-)$	10
$C_{p,max}(-)$	0.48			$V_{gas}(V)$	13.0	$P_{pv,nom}(KW)$	2.001

Scenario I: Constant Current Charging Mode

Wind speed starts at the rating value of the generator and sharply increases by 37.5% at t= 0.06 s.

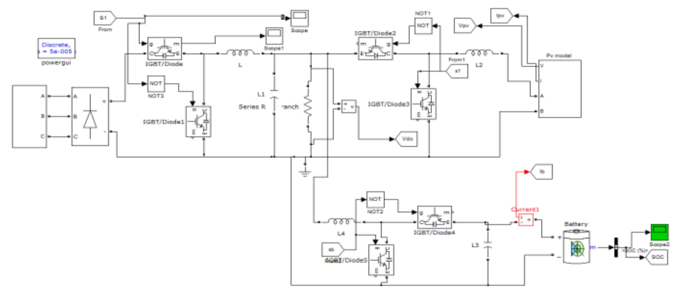


Figure 6: simulation circuit of the overall proposed DC microgrid

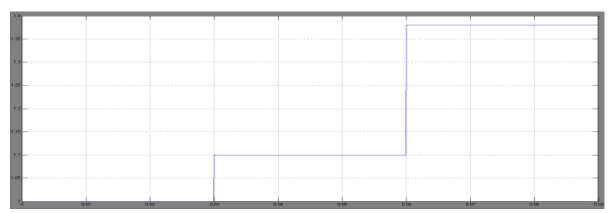


Figure 7: Normalized amounts of non-manipulated inputs

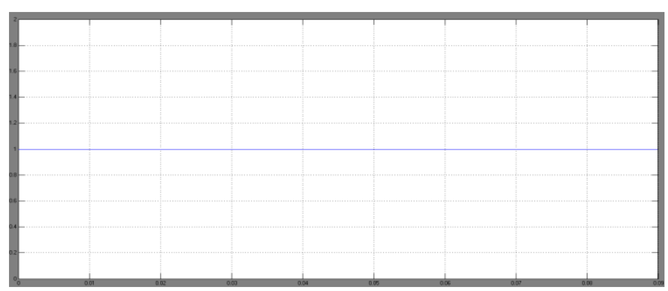


Figure 8: Pitch angle

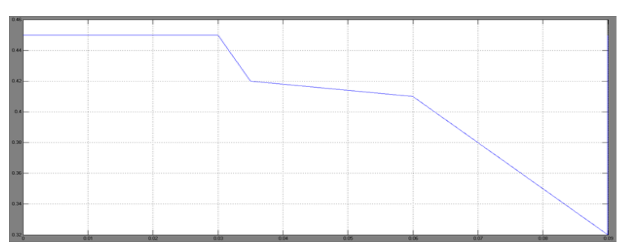


Figure 9: switching duty cycles of the wind

International Journal of Research
Available at https://edupediapublications.org/journals

e-ISSN: 2348-6848
p-ISSN: 2348-795X
Volume 04 Issue14
November 2017

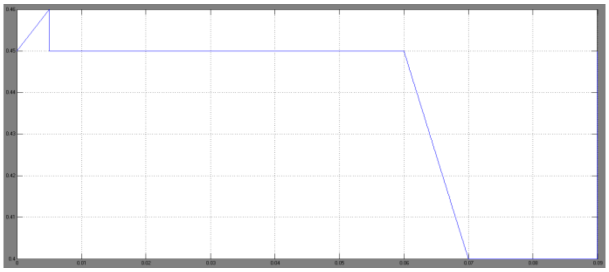


Figure 10: switching duty cycles of the solar

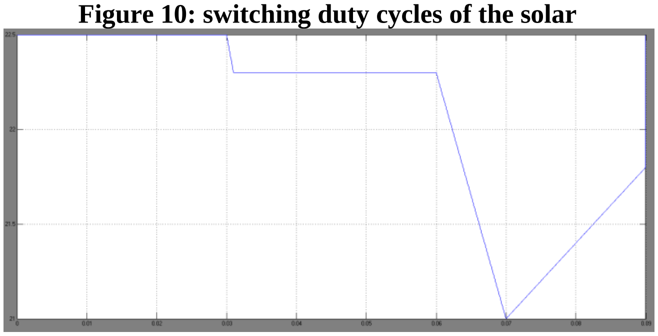


Figure 11: the wind turbine angular velocity

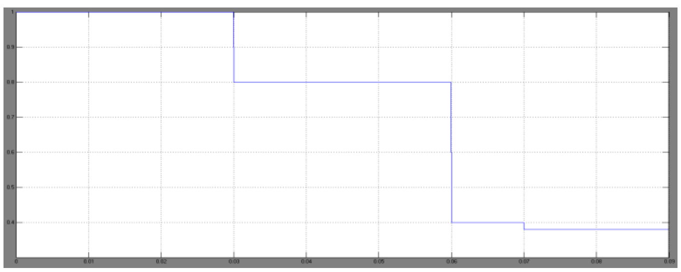


Figure 12: the wind turbine power coefficient; the PV array

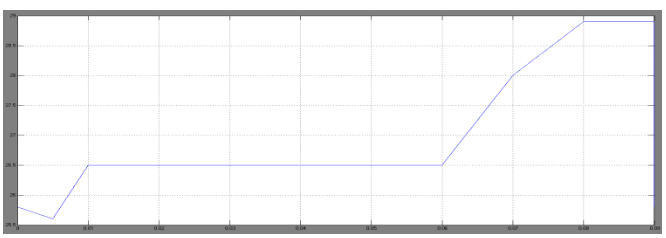


Figure 13: the wind turbine voltage

III. Hybrid photovoltaic-fuel cell system

Introduction

Hybrid power systems (HPS) combine two or more sources of renewable energy into one or more conventional energy sources. The renewable energy sources such as photovoltaic and wind do not deliver a constant power, but due to their complementarities their combination provides more continuous electrical output. Hybrid power systems are generally independent from large interconnected networks and are often used in remote areas. The purpose of a hybrid power system is to produce as much energy from renewable energy sources to ensure the load demand. In addition to sources of energy, a hybrid system may also include a DC or AC distribution system, a storage system, converters, filters and a control system for load management.

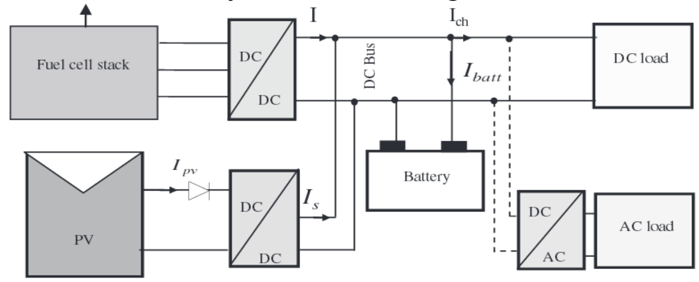


Figure 14: Description of a hybrid photovoltaic battery fuel cell

Modeling of the studied system

Modeling of the PV

The model studied in this work is represented by an equivalent circuit. This one consists of a single diode for the cell polarization function and two resistors (series and shunt) for the losses. Thus, it can thus be named "one diode model".

Hybrid PV/Fuel Cell System integrated to AC micro grid

The proposed system is represented in the simulink form under the Matlab. A complete system model composed of a hybrid energy source which is composed of Fuel Cell, PV Array and battery, Boost regulator , Inverter and load. PEMFC model, PV cell connected to a Ni-Metal Hydride battery model has been developed and simulated using MATLAB/Simulink program.

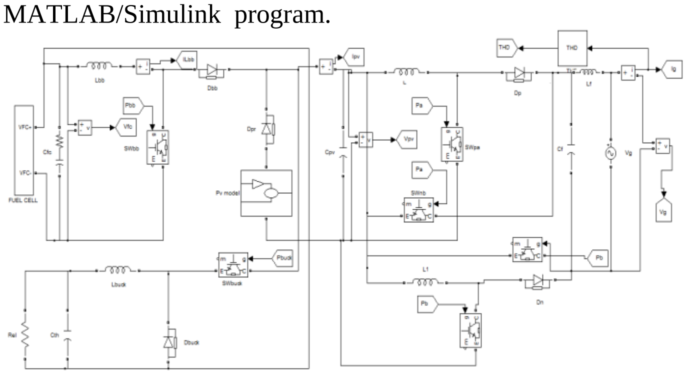
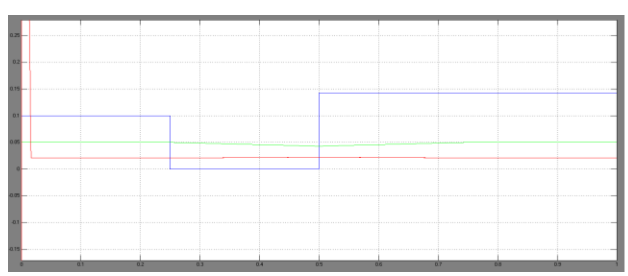


Figure 15: Simulation circuit of the proposed Hybrid PV-Fuel cell system



e-ISSN: 2348-6848
p-ISSN: 2348-795X
Volume 04 Issue14
November 2017

Figure 16: Simulation waveform of PV insolation, Temperature, and AC grid current THD

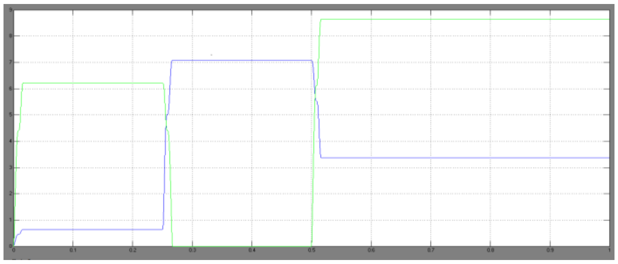


Figure 17: Fuel cell current and PV cell current

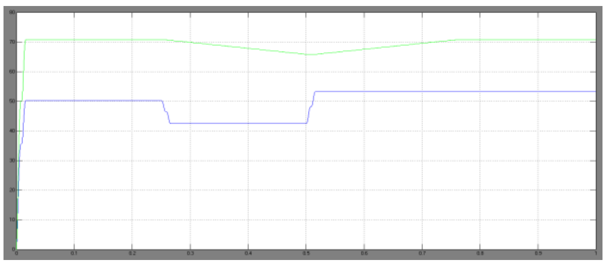


Figure 18: Fuel cell voltage and PV cell voltage

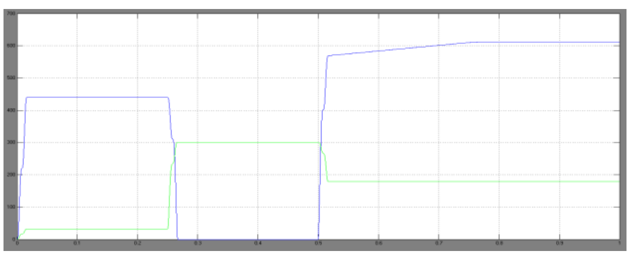


Figure 19: PV cell power and fuel cell power

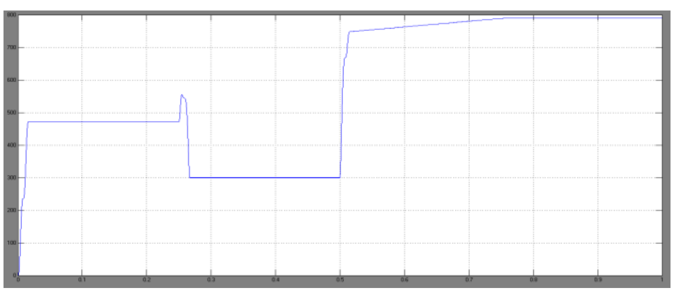


Figure 20: Total power (PV cell + Fuel cell)

IV. CONCLUSION

In this paper, we developed a novel optimal EMS that manages the energy flows across a standalone green dc microgrid, consisting of the wind, solar, and battery branches. A coordinated and multivariable online NMPC strategy has been developed to address, as the optimal EMS, three main control objectives of standalone dc microgrids. These objectives are the voltage level regulation, proportional power sharing, and battery management. In order to address these objectives, the developed EMS simultaneously controls the pitch angle of the wind turbine and the switching duty cycles of three dc-dc converters. It has been shown that the developed controller tracks the MPPs of the wind and solar branches within the normal conditions and curtails their generations during the under load conditions. The provided flexible generation curtailment strategy realizes the constant current-constant voltage charging regime that potentially increases the life span of the battery bank.

REFERENCES

[1] J. M. Guerrero, M. Chandorkar, T. Lee, and P. C. Loh, "Advanced Control Architectures for Intelligent Microgrids-Part I: Decentralized and Hierarchical Control," IEEE Trans. Ind. Electron., vol. 60, no. 4, pp. 1254–1262, 2013.

[2] R. S. Balog, W. W. Weaver, and P. T. Krein, "The load as an energy asset in a distributed DC smartgrid architecture," IEEE Trans. Smart Grid, vol. 3, no. 1, pp. 253–260, 2012.

[3] J. M. Guerrero, P. C. Loh, T. L. Lee, and M. Chandorkar, "Advanced Control Architectures for IntelligentMicrogrids-Part II: Power quality, energy storage, and AC/DC microgrids," IEEE Trans. Ind. Electron., vol. 60, no. 4, pp. 1263–1270, 2013.

[4] N. Eghtedarpour and E. Farjah, "Control strategy for distributed integration of photovoltaic and energy storage systems in DCmicro-grids," Renew. Energy, vol. 45, no. 0, pp. 96–110, 2012.

[5] D. Chen and L. Xu, "Autonomous DC voltage control of a DC microgrid with multiple slack terminals," IEEE Trans. Power Syst., vol. 27, no. 4, pp. 1897–1905, Nov. 2012.

Author Details:

K.R. Anugna Hinduja was born in Nalgonda, India, in 1993. She received the B.Tech and M.Tech. degrees from JNTUH University, India, in 2014 and 2016 respectively, and currently working as an Assistant Professor at "Swami Ramananda thirtha Institute of Technology" ,Nalgonda, Telangana, India.

V. Dhanunjaya, presently working as Assistant professor in B.V. Raju Institute of Technology Narsapur, Telangana, India. He received the B.Tech and M.Tech. degrees from JNTUH University, India, in 2010 and 2013 respectively His research area includes power semi conductor drives, Solar Power Applications, Renewable energy sources & Doubly Fed Induction Generators.