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Study on Dynamic Behavior of Photovoltaic Mixer Grinder

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ABSTRACT
This paper presents the dynamic behavior of a PWM controlled mixer motor drive fed from a PV panel. In particular, qualitative changes that occur in the behavior of motor current have been explored against variation in irradiance and load torque. The output from PV panel is used to charge a battery using a buck-boost converter whose duty cycle is controlled by applying perturb and observe algorithm for the purpose of maximum power point (mppt) tracking. This battery in turn supplies a mixer motor through a PWM controlled buck converter using PI controller. The buck converter has been operated in voltage mode control. In this study a universal motor has been considered for the mixer grinder application. The proposed application of PV panel for a 0.5hp mixer motor has been simulated using MATLAB software.
Keywords - Bifurcation, Chaos, Mixing, Mppt, Photovoltaic, Universal Motor.

I. INTRODUCTION

The need for modernization is the cause of the growing rate of urbanization and this has led to the construction of a large number of multistoried buildings. The obvious outcome of this is the increased demand for electrical energy which is an alarming fact considering the available amount of conventional energy resources. Modern civilization is thus becoming more and more conscious regarding the use of renewable sources of energy like wind, solar, tidal, geothermal etc. along with the conventional energy sources [1]- [4]. However, another feasible solution is to adopt the eco-friendly concept of green building The idea of Green building means efficient use of energy along with utilization of renewable energy resources. Among the available options for renewable energy, solar is the best choice for India considering its geographical location. Several investigations are present describing methods for harvesting and utilizing solar energy. Solar energy stations can either be standalone generating unit for supplying local load or can be grid connected depending on the availability of a grid. The combined idea of green building and grid connected solar station has also promoted smart metering [5] – [6]. The green building market in India is estimated to get double by 2022. Thus, analysis of the performance of a mixer grinder fed by PV panel is actually a need of the hour .

The voltage output obtained from a PV module is needed to be boosted up for any practical application. The obvious solution for stepping up the PV panel output is to connect a boost chopper at its output terminals [7] The voltage obtained from a solar photovoltaic cell depends on different factors like luminosity, tilt angle, atmospheric temperature etc.

and thus nonlinear in nature. Therefore, performance of the electrical load can exhibit different nonlinear behaviors like limit cycle oscillation, quasi-periodic and higher

periodic behaviors including chaos [7]-[13]. However, voltage gain of the same is limited by parasitic resistance of the switching device and reactive components present in the system. In order to avoid this problem, output voltage from the PV panel can be connected to either buck-boost converter or cuk converter.

The mixing application needs high starting torque and so a dc series motor can be the ideal choice. However, universal motor can also replace conventional dc series motor. In the literature of power electronics and drives many investigations are present describing nonlinear dynamics of a PWM chopper controlled dc series motor [14] – [15]. However, very little investigations are present for exploring the behavior of a photovoltaic system of mixer grinder. Therefore, in this study an attempt is made to present the nonlinear dynamics of a PWM controlled universal motor fed from a battery, the battery in turn being charged by a MPPT controlled buck-boost converter fed from a PV panel.

The organization of this paper is as follows. Section II describes the system along its mathematical model. The proposed system has been simulated in MATLAB software. The simulation results are present in section III. In particular, bifurcation behavior of the motor current against variation in in luminosity and load torque have been presented in this section. Moreover, calculation of maximum Lyapunov exponent for each bifurcation diagram.

II. SYSTEM DESCRIPTION

The equivalent circuit of the PV panel is shown in Fig.1. The output from PV panel is used for charging battery through a buck-boost converter whose duty cycle is controlled by using maximum power point tracking method employing the perturb and observe algoritm. This battery is used to drive the universal motor using a PWM controlled buck conveter. The Buck converter is operated in voltage control mode usong a PI control loop.The battery voltage although varies according to solar insolation, but voltage fluctuation is much slower than the frequency of carrier voltage. Thus the battery can be mathematically modeled as a constant voltage souce. The proposed photovoltaic application including a universal motor has been presnted in Fig.2.

A. Photovoltaic Panel

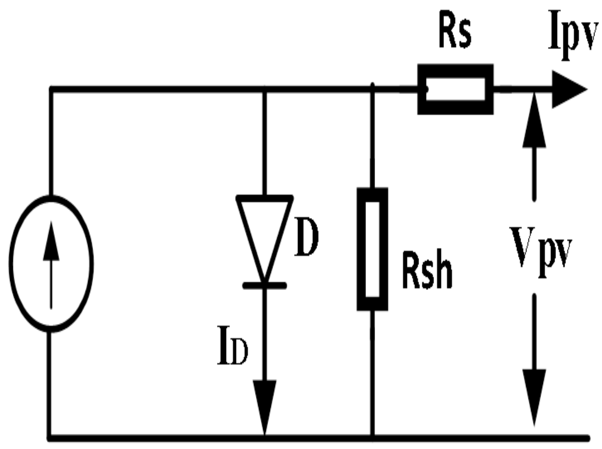

Fig. 1. Equivalent circuit of PV panel

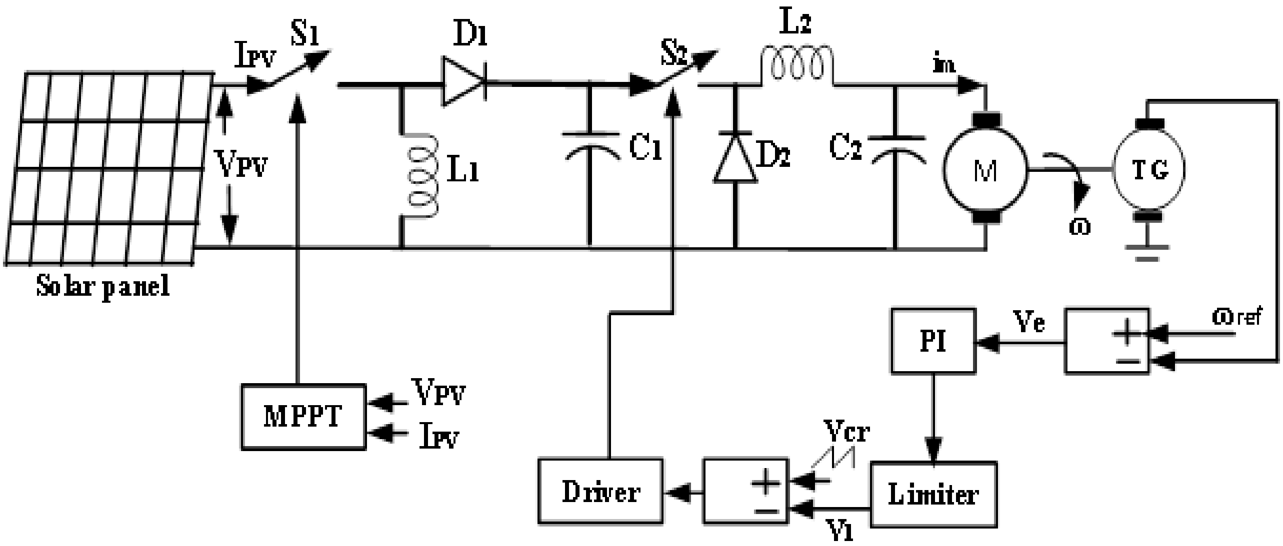

Fig. 2. Schematic diagram of PV panel fed mixer grinder with intermediate two stage power conversion

The V-I characteristic of the PV panel can be obtained by solving the transcendental equation as described in (1).

$$I_{PV} = I_{ph} - I_o\left[exp\left(\frac{q(V_{pv}+I_{pv}R_s)}{nKN_sT}\right) - 1\right] - \left(\frac{V_{pv}+I_{PV}R_S}{R_{sh}}\right)$$

(1)

The terms *n, K, Ns, T, q* in (1) represent ideality factor of the diode, Boltzmann's constant ($1.38X10^{-23}$ J/K), number of cells in series , operating temperature in Kelvin and charge of an electron ($1.6X10^{-19}$C) respectively. The photo current (I_{ph}) and saturation current (Io) in (1) take the forms as presented in (2) and (3) respectively.

$$I_{ph} = [I_{sc} + k_i(T - 298)]\frac{G}{1000} \qquad (2)$$

$$I_o = \frac{I_{sc}}{e^{\left(\frac{qV_{oc}}{nKN_sT}\right)-1}}\left(\frac{T}{T_n}\right)^3 e^{\left(\frac{qE_{go}\left(\frac{1}{T_n}-\frac{1}{T}\right)}{nK}\right)} \qquad (3)$$

The terms K_i, G, V_{oc}, I_{sc},, E_{go} in (2) and (3) represent short circuit current of the cell at 25˚C and 1000W/m2, solar irradiation in W/m2,open circuit voltage in volt, short circuit current in Ampere and band gap energy of the semiconductor in ev respectively.

B. Buck-Boost converter with MPPT Control Specifications

The components S_1, D_1, L_1 in Fig. 1 together form the buck-boost converter. The two switching states of the converter can be stated as state 1 and state 2. State 1 means S_1 is On and D_1 is in off state . However, in state 2 S2 turns off and d1 conducts to freewheel energy stored in inductor during state 1. Considering current through L1 and voltage across C_1 as the phase variables and considering switch S2 in off state the state equations in both the switching states take the form as in (4) and (5) respectively.

$$\begin{bmatrix} \frac{di_{L_1}}{dt} \\ \frac{dv_{C_1}}{dt} \end{bmatrix} = \begin{bmatrix} \frac{V_{PV}}{L_1} \\ \frac{i_{L_1}}{C1} \end{bmatrix} \qquad (4)$$

$$\begin{bmatrix} \frac{di_{L_1}}{dt} \\ \frac{dv_{C_1}}{dt} \end{bmatrix} = \begin{bmatrix} -\frac{v_{C_1}}{L_1} \\ -\frac{i_{L_1}}{C_1} \end{bmatrix} \qquad (5)$$

The duty cycle of the switch S_1 is controlled by perturb and observe algorithm as shown in Fig. 3 below.

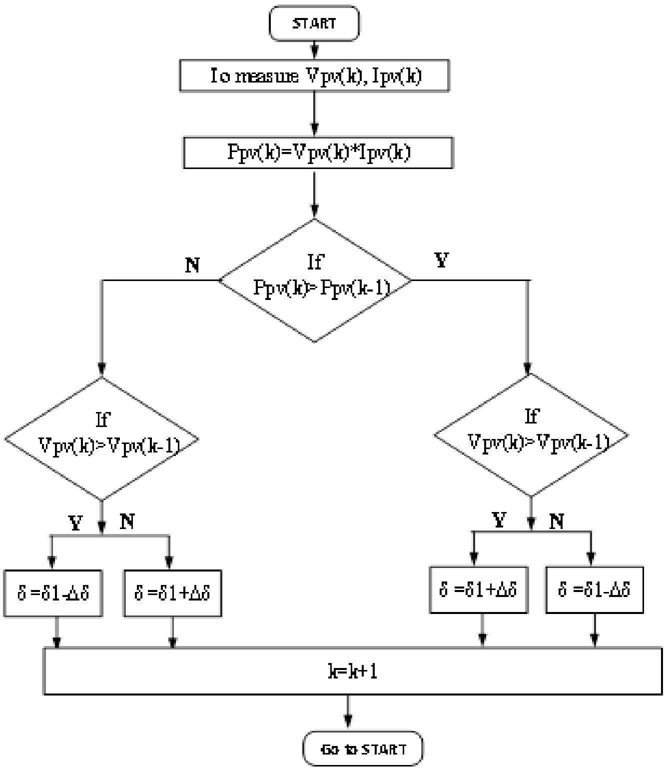

Fig. 3. Perturb and observe algorithm for maximum power point control

C. The Mixer Motor Drive

The universal motor acts aa load for the buck converter which is fed by the battery (C1) charged by buck-boost converter which is connected with the output terminal of PV panel. The switch S2, inductor L2 and diode D2 form the buck converter system. Considering device switching pulse for S2 as in Fig. 4, the two switching modes of buck

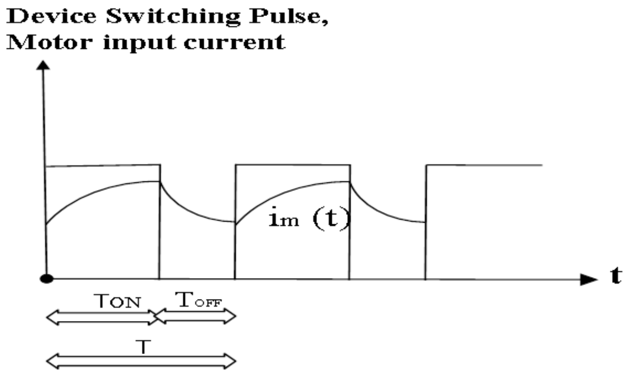

Fig. 4. Switching pulse for switch S_2

converter can be described as mode 1 (T_{ON})- when S_2 is on and D_2 is off and mode 2 (T_{OFF})in which S_2 remains in off state and D_2 conducts to freewheel energy stored in motor inductance during mode 1. The actual speed of the motor is compared with reference speed $\omega_{ref(t)}$ and the error voltage Ve(t) is fed to a PI controller with limiter. Output of the limiter circuit V_l (t) is compared with the carrier voltage $V_{cr}(t)$ which is a saw tooth waveform of amplitude A and switching period T as presented in (6).

$$V_{cr}(t) = \frac{A}{T}t \tag{6}$$

Considering gain of the Pi controller as kp- ki, the output of PI controller with limiter can be described as in (7)

$$V_l(t) = k_p\begin{pmatrix}\omega_{ref}(t)\\ -\omega(t)\end{pmatrix} + k_i\int\left(\omega_{ref}(t)-\omega(t)\right)dt$$

(7)

Assuming linear magnetic circuit of the motor and considering motor current $i_m(t)$, motor speed ω (t), current through L_2, voltage across C_2 and input to the integral controller as the phase variables x_1, x_2, x_3, x_4, x_5 respectively mathematical model of the drive system during mode 1take the form as in (8) and the same for mode 2 can be described by (9)

Mode-1

$$\begin{bmatrix}\dot{x_1}(t)\\ \dot{x_2}(t)\\ \dot{x_3}(t)\\ \dot{x_4}(t)\\ \dot{x_5}(t)\end{bmatrix} = \begin{bmatrix}\frac{x_4(t)-x_1(t)r_m-k_e x_1(t)x_2(t)}{l_m}\\ \frac{k_T x_1(t)x_1(t)-Bx_2(t)-T_L}{J}\\ \frac{D_{MPPT}V_{PV}-x_4(t)}{L_2}\\ \frac{1}{C_2}\left(x_4(t)-x_1(t)\right)\\ \omega_{ref}(t)-\omega(t)\end{bmatrix} \tag{8}$$

Mode-2

$$\begin{bmatrix}\dot{x_1}(t)\\ \dot{x_2}(t)\\ \dot{x_3}(t)\\ \dot{x_4}(t)\\ \dot{x_5}(t)\end{bmatrix} = \begin{bmatrix}\frac{-x_1(t)r_m-k_e x_1(t)x_2(t)}{l_m}\\ \frac{k_T x_1(t)x_1(t)-Bx_2(t)-T_L}{J}\\ \frac{D_{MPPT}V_{PV}-x_4(t)}{L_2}\\ \frac{1}{C_2}\left(x_4(t)-x_1(t)\right)\\ \omega_{ref}(t)-\omega(t)\end{bmatrix} \tag{9}$$

The terms k_e, k_T, r_m, l_m B, J , T_L, D_{MPPT} in (8) – (9) represent back emf constant, torque constant, armature resistance, armature inductance , viscous coefficient constant ,moment of inertia of the motor , load torque and duty cycle of the respectively.

III. SIMULATION RESULTS

The universal motor drive system showing application of PV panel has been simulated in MATLAB with following parameters as presented in Table 1.

TABLE1: Values of System Parameters

Sl. No	System parameters	
	Name of the parameter	Value
1	ki	0.0032
2	Tn	298
3	n	1.3
4	N_s	100
5	R_s	0.221Ω
6	R_{sh}	415Ω
7	B	0.001
8	J	0.001
9	r_m	30Ω
10	l_m	0.07H
9	T_L	1Nm
10	k_e	0.13
11	k_T	0.13
12	C_1	0.0047uF
13	C_2	0.0063uF
14	L_1, L_2	0.02H, 0.04H

The nature of variation of motor current against changes in luminous intensity is as shown in Fig. 5

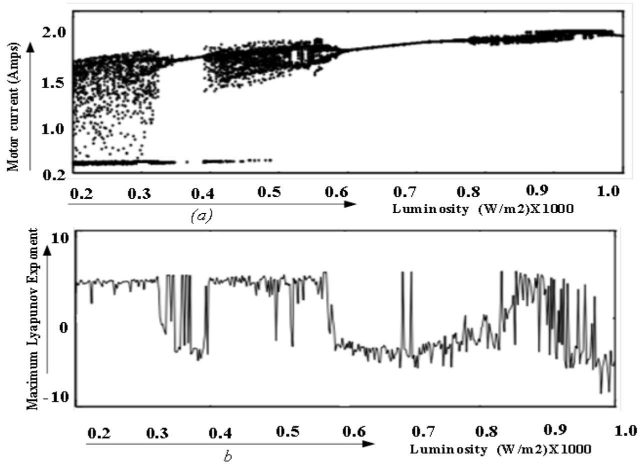

Fig. 5. Bifurcation behavior of motor current against variation in luminous intensity

a. Variation in motor current, b. variation in maximum Lyapunov exponent

All the bifurcation diagrams in this study have been obtained by stroboscopic sampling of the phase variables. Thus, in the bifurcation behavior of any phase variable, if the particular phase variable has only one value corresponding to a value of the bifurcation parameter, then it will be treated as period-1 behavior. If, however the phase variable possesses two values for any setting of the bifurcation parameter then the system is said to have period-2 evolution. Similarly, when the phase variable takes infinite values for any setting of the bifurcation parameter, the system is said to have chaotic evolution. It has been observed from Fig. 5 that for low value of luminous intensity the motor current shows chaotic evolution. Chaotic dynamics can be characterized by positive Lyapunov exponent which means occurrence of chaotic motion inside a mixing vessel. However, when luminous intensity increases beyond 600W/m^2 motor current shows stable nominal period-1 motion. Bifurcation behavior of motor current against variation in per unit value of load torque is presented in Fig. 6. It has been observed from Fig. 6 that for low values of load torque, evolution of motor current is periodic. However, when per unit value of load torque reaches nearly the value of 0.3, period doubling bifurcation takes place. Further period doubling bifurcation takes place, when per unit value of load torque reaches nearly the value of 0.35. Chaotic evolution of motor current is found after per unit value of load torque increases beyond 0.4. It is interesting to note that the drive system has period-1 motion for a short span of variation in per unit value of load torque ranges between 0.67 to 0.69 approximately. Occurrence of period -1 motion has been quantified by negative value of maximum Lyapunov exponent.

IV.CONCLUSION

This study is intended to explore effect of variation in solar insolation on the performance of mixer motor. This analysis is very helpful for implementing the idea solar powered mixer grinder which is indeed a smart idea for the green building.

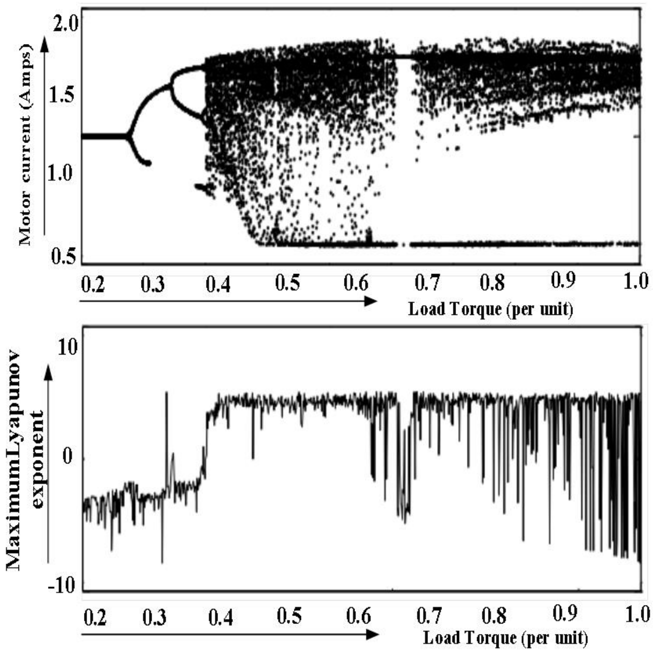

Fig. 6. Bifurcation behavior of motor current against variation in per unit value of load torque

Investigations show that, even with low value of solar insolation the mixer motor can run satisfactorily, rather better as mixing is considered. An attempt is also made is to investigate effect of variation in load torque on the performance of the drive motor and it has been found that for the solar mixer grinder mixing efficiency increases with high value of load torque. The increase in mixing efficiency can be claimed as occurrence of chaos e enhances mixing process.

V. REFERENCES

[1]. M. N. Tandjaoui and C. Benachaiba, “Role of Power Electronics in Grid Integration of Renewable Energy Systems”, Journal of Electrical Engineering

[2]. Małgorzata Bobrowska-Rafał, “Grid Synchronization and Control of Three-Level Three-Phase Grid-Connected Converters based on Symmetrical Components Extraction during Voltage Dips”, Warsaw University of Technology, 2013..

[3]. Euzeli C.dos Santos Jr., “A Bidirectional Dc-Ac Converter”, IEEE Conference 2012.

[4]. Amakye Dickson Ntoni. “Control of Inverters to Support Bidirectional Power Flow in Grid Connected Systems”, International Journal of Research in Engineering and Technology, May 2014.

[5]. Sharma Konark and Saini Lalit Mohan, "Performance analysis of smart metering for smart grid: An overview", Renewable & Sustainable Energy Reviews, vol. 49, pp. 720-735, SEP 2015.

[6]. Labeodan Timilehin, Aduda Kennedy, Boxem Gert et al., "On the application of multi-agent systems in buildings for improved building operations performance and smart grid interaction- A survey", Renewable & Sustainable Energy Reviews, vol. 50, pp. 1405-1414, OCT 2015.

[7]. D. Petreus, D. Moga, A. Rusu, T. Patarau, M. Munteanu, “Photovoltaic System with Smart Tracking of the Optimal Working Point, ” Advances in Electrical and Computer Engineering, vol. 10, no. 3, pp. 40-47, 2010. Available: http://dx.doi.org/10.4316/ AECE. 2010.03007

[8]. M. J. Vasallo Vázquez, J. M. Andújar Márquez, and F. S. Manzano,“A Methodology for Optimizing Stand-Alone PV-System Size Using Parallel-Connected DC/DC Converters, ” IEEE Transactions on Industrial Electronics , vol. 55, no. 7, pp. 2664-2673, 2008

[9]. El Aroudi, “A Prediction of subharmonic oscillation in a PV-fed quadratic boost converter with nonlinear inductors” , Proceedings of the IEEE International

Symposium on Circuits and Systems (ISCAS), Florence, Italy, 27–30 May 2018; pp. 1–5.

[10]. D. Langarica-Cordoba, L.; Diaz-Saldierna, H.; Leyva-Ramos, J. “Fuel-cell energy processing using a quadratic boost converter for high conversion ratios”, Proceedings of the IEEE 6th International Symposium on Power Electronics for Distributed Generation Systems (PEDG), Aachen, Germany, 22–25 June 2015, pp. 1–7

[11]. Zhioua, M., El Aroudi, A. & Belghith, S. “Analysis of bifurcation behavior in a current-fed boost converter for PV systems,” IEEE Multi-Conf. Systems, Signals & Devices, 2015,pp. 1–6

[12]. Haroun, R., El Aroudi, A., Cid-Pastor, A., Garica, G., Olalla, C. & Martinez-Salamero, L.:“Impedance matching in photovoltaic systems using cascaded boost converters and sliding-mode control,” IEEE Trans. Power Electron. 2015.30, pp.3185–3199.

[13]. Zamani, N., Ataei, M. & Niroomand, M. “Analysis and control of chaotic behavior in boost converter by ramp compensation based on Lyapunov exponentsassignment: Theoretical and experimental investigation,” Chaos Solit. Fract.2015, 81, 20–29.

[14]. Kundu, S., Chatterjee, S., Chakrabarty, K.” Bifurcation behavior of PWM controlled DC series motor drive”, IET power Electronics, September 2016, ISSN: 1755-4535.

[15]. Kundu, S., Chatterjee, S., Chakrabarty, K.” Co-existence of multiple attractors in PWM controlled DC drives’, The European Physical Journal Special Topics, 2013, 222(3-4),pp. 699-709.