Robust fully synergetic control of PMSM-Flywheel Energy Storage System FESS integrated in standalone hybrid PV-wind system

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Abstract: The main purpose of the present paper is to build a robust synergestic control of the permanent magnet synchronous machine (PMSM), that drives a flywheel to form an energy storage system that is integrated into a hybrid PV-wind system. The biggest inconvenience of the exploitation of clean sustainable sources like solar and wind energies is the continuous variation of the weather conditions, appearing as a frequent change in the wind currents (wind speed) and solar radiations. This problem causes a fluctuation in electricity production by the wind turbines and photovoltaic panels, which is a serious drawback particularly in the isolated standalone system when the system is incapable of generating demanding power. Thus, the use of hybrid system with more than one source, especially when it is supported by an energy storage system like FESS, is an effective solution for this drawback. It is able to re-generate power when the hybrid PV-wind system cannot generate enough electricity. Moreover, the synergetic control guarantees fast response, asymptotic stability of the closed-loop system in the all-range operating condition, and system robustness in presence of parameter variation. Computational simulation results confirm that the proposed method consistently outperforms other techniques and proves its effectiveness and benefits of using such a system.

Keywords: Wind energy conversion system WECS, photovoltaic system PV, Hybrid PV-wind system, permanent magnet synchronous machine PMSM, Synergetic control SC, flywheel energy storage system FESS.

1. Introduction

Conventional (fossil) energy has been exploited and used for a long time to produce power, but this type of energy came with drawbacks that make the majority of the world return to searching for inexhaustible climate-friendly alternatives. The world's most prominent energy resources to exploiting them are solar and wind energies distinguished by being clean and renewable. The 1973 energy crisis (Sahin, 2004) and the Russian-Ukrainian war in 2022 have led to a keenness to strengthen the work of these alternatives.

Wind energy is one of the most interesting renewable energies. It has received substantial attention as a clean energy source in recent years (Lin et al., 2018; Mousa et al., 2019; Wang & Bo, 2022). For this reason, the installed wind turbines around the World have grown fast in the last two decades from 440 GW in 2000 to 760 GW in 2020 (Blaabjerg et al., 2019).

Solar energy is the most abundant energy on the Planet. It is a sustainable energy par excellence with high potential and huge availability. According to expertise previsions, solar energy will be the highest exploited renewable energy source by at least 2040, accounting for 28% of electricity consumption in the World ("erec.org -", 2005).

The main advantage of hybrid renewable energy systems is the combination of two or more renewable energy sources to produce electricity, which increases their reliability, efficiency and energy availability compared to a single renewable energy source (Erdinc & Uzunoglu, 2012).

When the wind speed and solar radiations are high enough and the produced electrical energy is more than what is required, that extra power must be stored in other forms to be extracted later and used if the solar array and wind currents are unable to provide sufficient power.

There are many kinds of energy storage systems (ESS) as batteries, super-capacitors, superconductor inductors and flywheels. The flywheel system converts the additional generated power to kinetic energy where it is driven by an electrical machine (Ghedamsi et al., 2008) which is operating in this case as a motor, the flywheel starts the rotor of the electric machine which now works like a generator and converts the stored energy back into electrical energy.

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In the FESS, several types of electrical machines can be utilized like the squirrel cage inductor machine (SCIM), the double-fed inductor machine (DFIM) and the permanent magnet synchronous machine (PMSM). When the PMSM is used in the FESS, it offers sundry pros like high efficiency, awesome reliability, the possibility of working as a motor or generator interchangeably and the ease in the development and implementation of its control process that make it controllable by any control methods successfully as the vector control, the sliding mode control or even the based-on synergetic theory control.

The main advantages of synergistic theory-based control are: Firstly, it deals with all parametric and non-parametric uncertainties, which is not possible in linear control techniques. Secondly, the SC provides a very fast response, close to closed-loop system stability under all operating conditions and system robustness even in the presence of a difference in parameters (Guermit et al., 2019).

The novelty of this paper represents the adaptation of the synergetic control for the PMSM-Flywheel energy storage system for the first time in a published paper. A synergetic controller model of PMSM driving a flywheel will be developed and tested through simulations to get a deep idea about the FESS and the SC when used in a hybrid PV-wind system.

2. State of the art

There are several classifications of energy storage systems, as they can be classified according to their capacity into large or small storage systems, according to their working principle in terms of converting electrical energy into chemical, mechanical or potential, or according to its storage duration. In this paper, storage duration will be considered a basic criterion for the classification of these systems.

Energy storage systems are characterized by the storage time in which they can store energy and are divided into two main parts: SSE with a short storage period (stockage by supercapacitors, by superconducting coils, and by using a flywheel) and SSE with long storage period (stockage by batteries, by compressed air, and by hydraulic pumping). Each type has its own purposes, uses, advantages and disadvantages.

3. Modelling of the PMSM - flywheel energy storage system

3.1. Work principle of the FESS

In the past decade, the industry has rediscovered the flywheel energy storage system thanks to its advantages over other ESS (Hebner et al., 2002)

However, FESS has found definite application in improving the quality of electrical power, with respect to voltage and frequency within predetermined limits. With their high dynamics, long life, and good efficiency, FES systems are well-suited for short-term storage systems, which are generally sufficient to improve the quality of electric power (Cimuca et al., 2010; Cimuca et al., 2006; Hebner et al., 2002; Lawrence et al., 2003).

Like any ESS, the FESS is based-on the reversible transformation of energy. During storage, the electrical energy is converted into mechanical energy through the electric motor, while the mechanical energy is stored in the flywheel as kinetic energy. Yet, in the discharge phase, the stored mechanical energy in the flywheel is reconverted into electrical energy by the electric generator. The operating speed is imposed by the electronic power converter, which imposes the direction of transfer of energy through the electrical machine (Cimuca, 2005; Nemsi et al., 2016) (Figure 1).

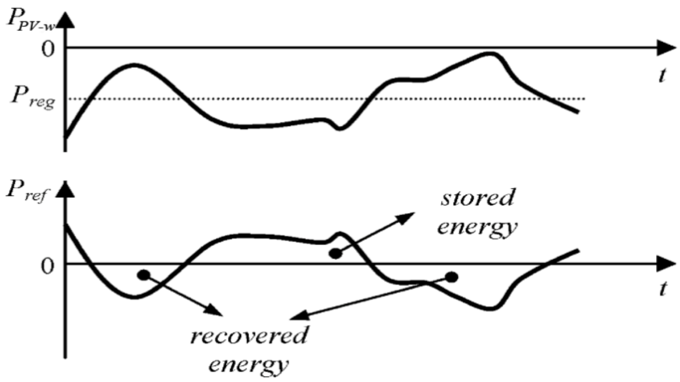

Figure 1. FESS's working principle

3.2. The mechanical part of the FESS

The mechanical organ of the FESS is represented by the flywheel itself. The kinetic energy of the flywheel is:

$$E_c = J_f \frac{\Omega^2}{2} \tag{1}$$

Whereas

J_f is the flywheel inertia.

The reference power P_{ref} of the FESS is the subtract of the regulation power P_{reg} which is the demanded power according to the connected load in the system from the generated power through the hybrid PV-wind group $P_{PV\text{-}w}$. So:

$$P_{ref} = P_{PV-w} - P_{reg} \tag{2}$$

And the reference kinetic energy is:

$$E_{c-ref} = E_{c0} + \int_{t_1}^{t_2} P_{reg}.dt \tag{3}$$

While

E_{c0} is the initial kinetic energy of the flywheel.

By substitution of Equation No. 3 Equation No. 1, the speed reference will be:

$$\Omega^* = \sqrt{\frac{2E_{c-ref}}{J_f}} \tag{4}$$

The latest term is the reference speed that will have been provided to the speed synergetic controller which will be developed in the next section.

3.3. The electrical part

Now, it is time for developing the mathematical model of the PMSM as the electrical machine that assures the reversible transformation between the kinetic and electrical energy.

This work deals with the control process not the machine's structure. So, to facilitate and simplify the mathematical model, the air gap is assumed to be perfectly uniform and constant so $L_d=L_q=L_s$, and the rotor permanent magnetic field is distributed in a sine waveform in this air gap (Beghdadi et al., 2019).

By using of unified d_q synchronous system, the two d_q components of stator voltage will be:

$$\begin{cases} V_d = R_s I_d + L_s \dot{I}_d - p\Omega L_s I_q \\ V_q = R_s I_q + L_s \dot{I}_q + p\Omega L_s I_d + p\Omega\Psi_0 \end{cases} \quad (5)$$

The magnetic equation:

$$T_{em} = p\Psi_{d0} I_q \quad (6)$$

And the mechanical equation:

$$\dot{\Omega} = \frac{T_{em} - C_r - f\Omega}{pJ} \quad (7)$$

Whereas

- L_s: the stator inductor;
- L_d/L_q: stator direct/ quadrature inductors;
- V_d/V_q: stator direct/ quadrature voltages;
- R_s: stator resistance;
- I_d/I_q: stator direct/ quadrature currents;
- Ψ_{d0}: the rotor permanent flux;
- Ω: machine speed;
- Ω: machine acceleration;
- p: machine number of poles;
- T_{em}: the machine torque;
- C_r: load torque;
- f: Damping coefficient;
- J: Inertia.

In Equation No. 6, the machine torque is only in function of the I_q current ($p\psi_{d0}$=constant) which means that the machine torque and the machine speed can be controlled just by the I_q current (Beghdadi et al., 2019).

In the PMSM situation, the rotor produces a permanent magnetic flux hence it is constant, so there is no need to control the I_d current. Still, in most cases, the I_d current set to be zero equal to reduce the Joule losses that rise the system efficiency (Retif, 2008).

4. Synergetic control of the FESS

4.1. Synergetic theory

Synergy is the teamwork of many factors. In other words, the synergy can be defined as a collaboration in which different factors operate collectively to achieve a better and greater macro-effect than when each factor works alone. For example, many muscles intervene to assure one precise movement in the human body, known as muscle synergy. The cooperation of the front deltoid, chest and triceps in any pushing movement becomes more complicated if every muscle works independently from the others.

4.2. Synergetic control development

Any n-order nonlinear system can be modelled as next equation:

$$\dot{x} = f(x,u,t) \quad (8)$$

where x, u and t are the state vector, the control vector, and time respectively.

The synergetic control SC can be viewed at as a gathering of analytical approaches (Kolesnikov et al., 2000; Ni et al., 2014) while its algorithm is described in detail in the following steps:

A. Choosing the macro-variables Ψ_s which can be simple linear relations or combinations between the system variables (Laribi et al., 2013), reducing the order of the controlled system. In other words, controlling a single macro-variable for a control channel instead of controlling several variables.

The main goal of SC is forcing the system to follow the manifold $\Psi_s=0$.

B. Develop the dynamic evolution equation of the macro-variable as:

$$\mathrm{T}\dot{\Psi}_s + \varphi(\Psi_s) = 0 \tag{9}$$

where T is a control parameter and φ is a function of the macro-variable Ψ_s must be carefully selected to assure the stability of the control, which is subject to two conditions: $\varphi(0)=0$ and $\varphi(\Psi_s).\Psi_s>0$.

It is easier to set $\varphi=\Psi_s$ to assure the previous conditions and the dynamic evolution equation becomes:

$$\mathrm{T}\dot{\Psi}_s + \Psi_s = 0 \tag{10}$$

C. The Equation No. 10 can be written as following:

$$\mathrm{T}\frac{d\Psi_s}{dx} f(x,u,t) + \Psi_s = 0 \tag{11}$$

D. Solving Equation No. 11 to have the control vector *u* where:

$$u = g(x, \mathrm{T}, \Psi_s, t) \tag{12}$$

The obtained control vector ensures that the controlled system variables effectively track and maintain their references with the best possible performance.

4.3. Synergetic control of the system flywheel - PMSM

In the speed control channel, a macro-variable Ψ_s must be chosen. Because the reference is machine speed. It is very helpful to set the macro-variable as (Zhao & Wang, 2018):

$$\Psi_s = K_1\left(\Omega^* - \Omega\right) + K_2\int\left(\Omega^* - \Omega\right).dt \tag{13}$$

And by the substitution of Equation No. 13 in Equation No. 10 give:

$$\mathrm{T}_1(-K_1\dot{\Omega} + K_2\left(\Omega^* - \Omega\right) + K_1\left(\Omega^* - \Omega\right)) + K_2\int\left(\Omega^* - \Omega\right).dt = 0 \tag{14}$$

While Ω^* is the reference speed. T_1, K_1, and K_2 are SC parameters to manipulate the control performance, stability and accuracy and to make it faster (tiny settling time) and more stable.

Finally, by the substitution of Equation No. 2 and Equation No. 10 in Equation No. 1 and after simplifying the V_q^* becomes:

$$V_q^* = R_s\left(\frac{J}{p\Psi_{d0}}\left(\frac{C_r + f\Omega}{J} + \left(\frac{1}{\mathrm{T}_1} + \frac{K_2}{K_1}\right)\left(\Omega^* - \Omega\right)\right) + \frac{K_2}{\mathrm{T}_1 K_1}\int\left(\Omega^* - \Omega\right).dt\right) + L_s I_q + p\Omega L_s I_d + p\Omega\Psi_{d0} \tag{15}$$

solving Equation No. 15 provides the require stator quadrature voltage reference V_q^* to assure the tracking of the reference speed by the machine speed. The control process will be tested in the simulation section before its integration in the FESS.

In the other channel, the I_d current can only be controlled with a simple conventional PI regulator as it will be set to be zero and has low sensitivity to the machine parameters. Therefore, there is no need for a robust control method.

But; in order to have full synergetic control and to ensure the complete decoupling of V_d and V_q control axes, a synergetic current controller will have to be developed in the next (Figure 2).

Same steps as the previous synergetic controller where:

The macro-variable will be:

$$\Psi_s = K_3\left(I_d^* - I_d\right) + K_4\int\left(I_d^* - I_d\right).dt \tag{16}$$

The dynamic equation:

$$\mathrm{T}_2(-K_3 I_d + K_4\left(I_d^* - I_d\right) + K_3\left(I_d^* - I_d\right)) + K_4\int\left(I_d^* - I_d\right).dt = 0 \tag{17}$$

The reference voltage:

$$V_d^* = R_s I_d + L_s((\left(I_d^* - I_d\right) + \frac{K_4}{K_3}\left(I_d^* - I_d\right)) + \frac{K_4}{\mathrm{T}_2\, K_3}\int\left(I_d^* - I_d\right).dt) - p\Omega L_s I_q \tag{18}$$

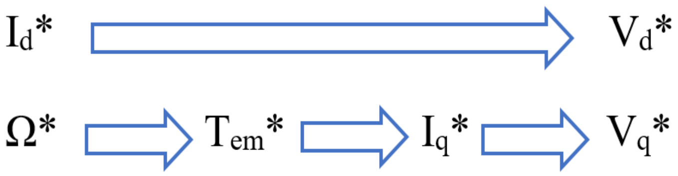

Figure 2. Synergetic control of the PMSM process

5. Simulation results and discussion

All the following simulations have been developed using **MATLAB/SIMULINK (2021a/9.1)** environment. The main goal of the next simulations is to integrate the controlled PMSM by synergetic control in the flywheel energy storage system FESS.

Before doing that, it will be considered that the reference which will be provided to the synergetic controller will be the machine speed according to the error between generated power and regulation power. The synergetic controller must be tested under normal conditions for better evaluation of its performance, accuracy, stability, settling time and overshoot then integrated into the FESS as figures out in (Figure 3).

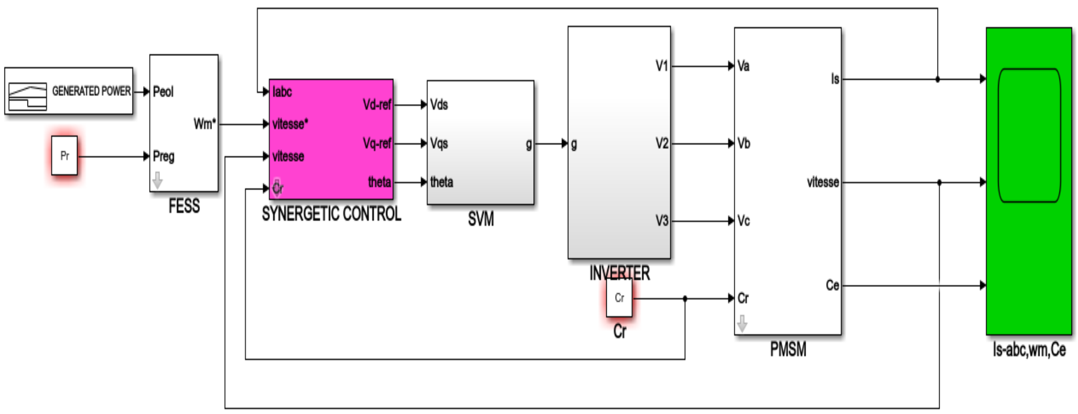

Figure 3. FESS control scheme

5.1. Evaluation of the synergetic controllers

Before the introduction of synergetic control in the overall system, the evaluation of it should be done in controlling the machine speed to follow its reference (Figure 4) and I_d current in order to ensure its quality and effectiveness before relying on it in controlling the system as a whole.

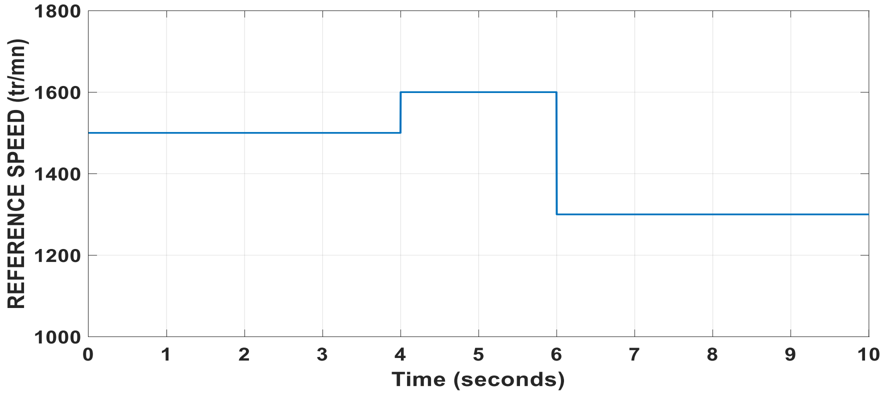

Figure 4. Machine reference speed

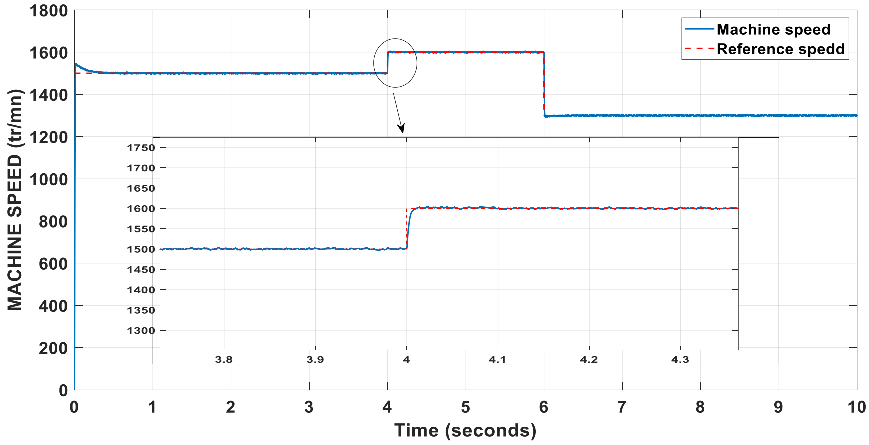

Figure 5. Machine speed

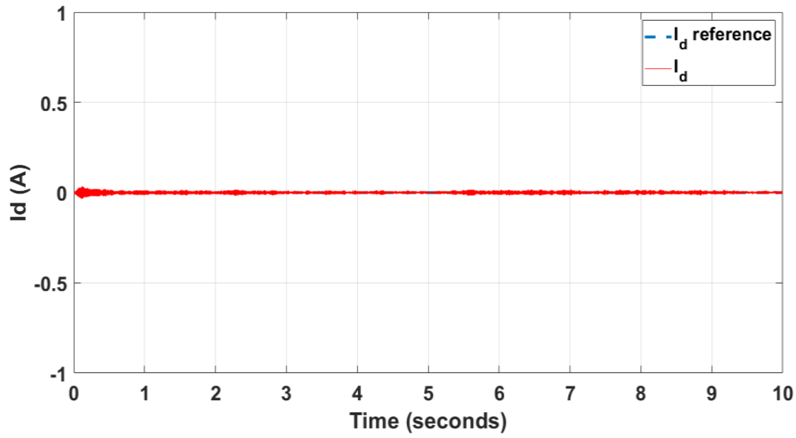

Figure 6. Machine stator direct current I_d

As it is shown in the Figure 5, the machine speed follows its reference very effectively with very little settling time, with high accuracy and without any overshoot.

The settling time is smaller than 0.01s and that is an excellent value. There are some neglectable oscillations in the machine speed around its reference, but with very low value (less than 0.05% at the maximum).

These oscillations exist due to the presence of harmonics in the stator currents and voltages because of the use of the bidirectional converter (inverter).

In Figure 6, the I_d current in its turn keeps up its reference perfectly without any chattering, overshoot, or oscillation, despite it dependency on the other current I_q and the speed. These performance, stability and accuracy are too hard if not impossible to get with linear control methods like vector control, DTC and scalar control even with non-linear methods as the sliding mode (chattering problem drawback).

After the successful evaluation of the synergetic control on the PMSM, the machine will be integrated into FESS.

5.2. integration of the controlled PMSM by synergetic control in the storage system

Now, after making sure of the effectiveness and accuracy of the synergetic control, it is time to include the controlled PMSM by this control method in the energy storage system FESS, and the result is as follows:

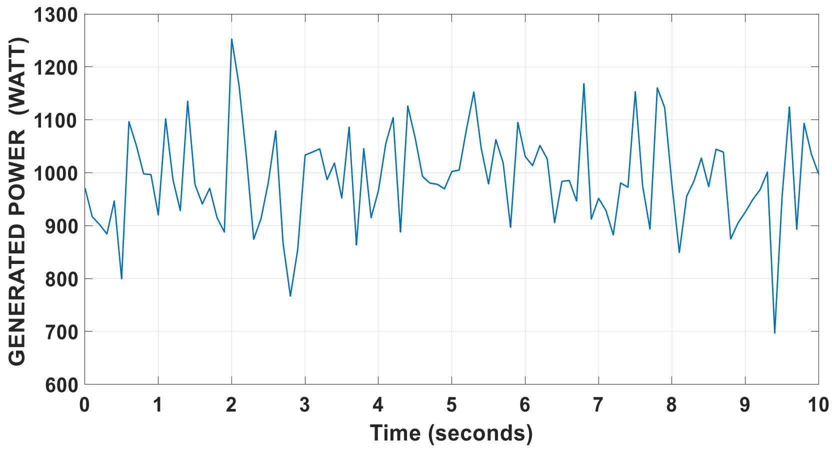

Figure 7. The generated electrical power $P_{PV\text{-}w}$ from the PV-wind hybrid system

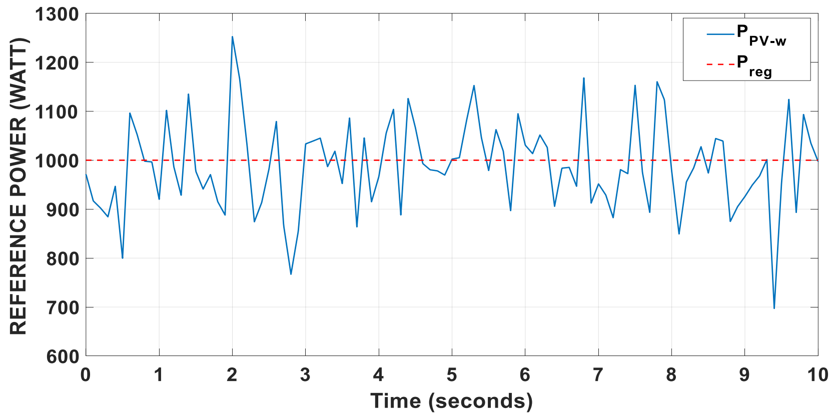

Figure 8. Comparison between the generated power $P_{PV\text{-}w}$ and the power of regulation P_{reg}

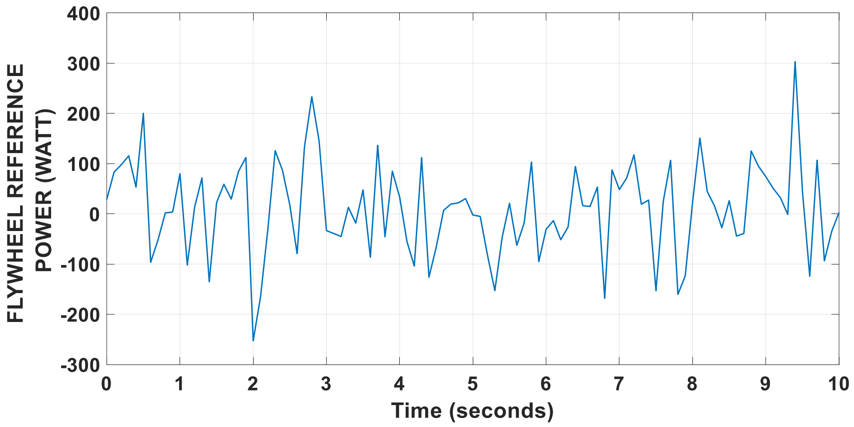

Figure 9. Flywheel reference power (error between $P_{PV\text{-}w}$ and P_{reg})

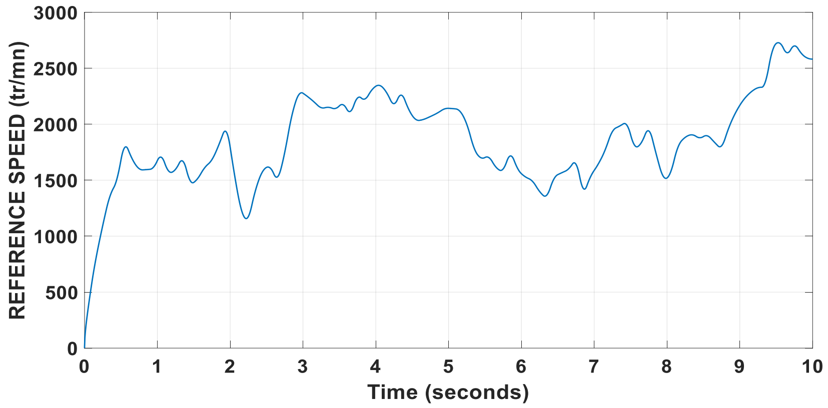

Figure 10. Machine reference speed

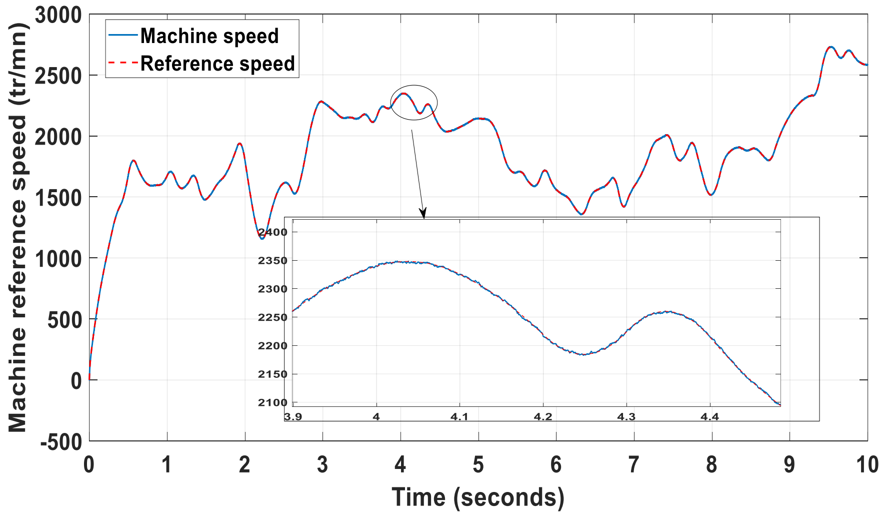

Figure 11. Machine speed

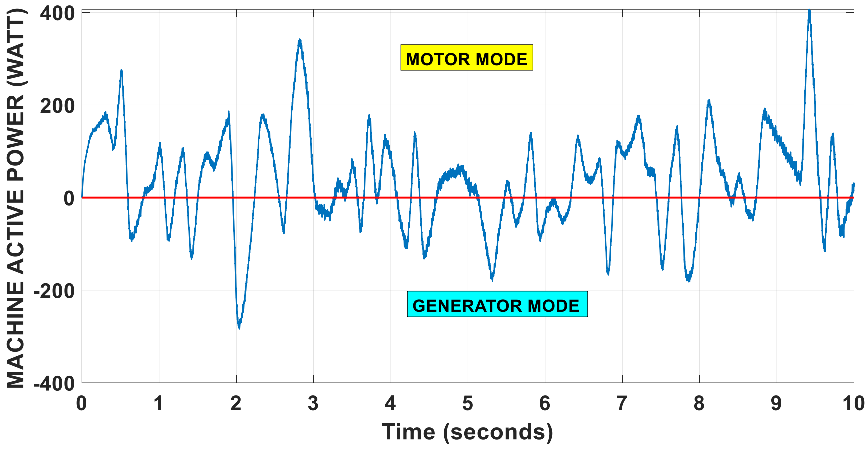

Figure 12. Machine active power

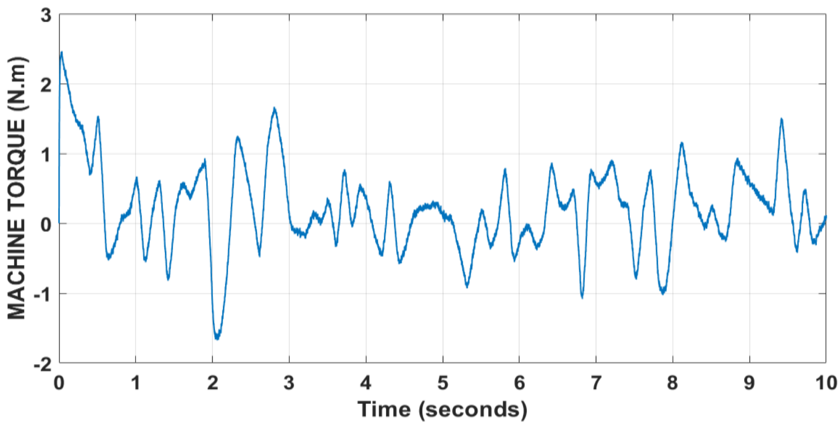

Figure 13. Machine torque

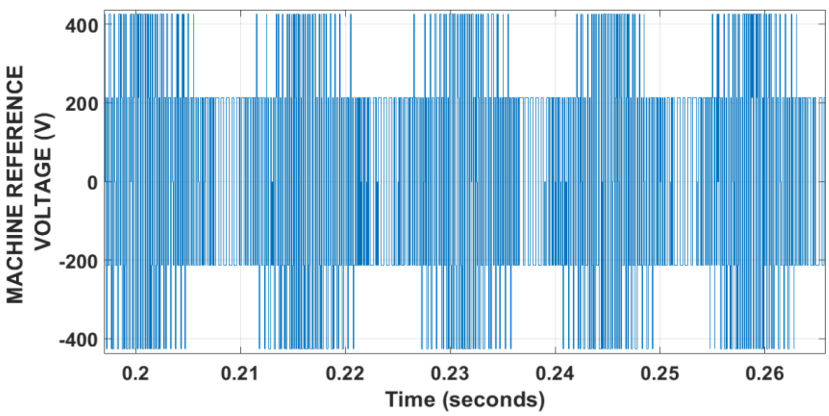

Figure 14. Machine stator voltage (phase 1)

The regulation power P_{reg} is set to be constant and equal to 1000 Watt. Moreover, this power is compared to the generated power P_{PV-w} to get the reference power of the FESS which is shown in Figure 7, Figure 8 and Figure 9.

Based on this reference power, the speed computer supplies the FESS reference speed to the synergic speed controller to calculate the machine reference stator voltage V_q* (Figure 10).

As it is seen in Figure 11, the machine speed keeps up and tracks effectively its reference to allow the system to generate or store the reference power perfectly.

Same as in the previous section, only with a PMSM. The SC offers very high performance with high accuracy, neglectable oscillations, without any chattering phenomenon, and very stable response.

The machine's active power and torque in Figure 12 and Figure 13 have shown that the machine operates interchangeably in both modes. The machine works as a motor in the charging period where it drives the flywheel. In the discharge phase, the machine turns out to be a generator and is driven by the flywheel where the stored kinetic energy converts to electrical energy by the generator.

From the above, the simulation results clearly demonstrated the successful implementation of the synergistic control of the PMSM-Flywheel energy storage system. All simulation goals are achieved where the speed follows its reference almost perfectly and the electric machine acts as a motor in the charging phase and a generator in the discharging phase.

Table 1. Simulation parameters

Type of parameters	Designation	Symbol	Value
Flywheel	Inertia, Flywheel load torque.	J_f, C_r	0.003 N.m.s/rad, 0.1N.m
PMSM	Rated power, Stator resistor, Stator inductor, Inertia, Rotor permanent magnetic flux.	P_n, R_s, L_s, J, Ψ_{d0}	100KW, 0.6Ω, 1.4mH, 0.00417 N.m.s/rad, 0.9 Wb
Synergetic control		T_1, K_1, K_2 T_2,K_3,K_4	8.42e-8, 13.2349, 2.5356 8.42e-8,102,1000

6. Conclusion

In this work a robust advanced based on synergetic theory control of a PMSM-Flywheel energy storage integrated in hybrid PV-wind system was developed and demonstrated.

The hybridization of solar and wind energies in one system assures more stable electrical power production where both sources collaborate to improve the continuity of the service especially when it is enhanced with a flywheel energy storage system.

The FESS is an excellent tool for short-time energy storage to use as backup energy and improve the generated power quality due to its high efficiency, long life, and low cost compared to other ESS.

The synergetic control offers robustness against system parameters variation, a very stable system state, high accuracy, without any chattering, and high performance particularity when it is used to control the machine speed, and that is what was proved in the above simulation.

The synergetic control can be adapted to any electrical machine to provide a great performance and improves the control results in quality especially when it is used to drive the PMSM where it provides a tangible improvement.

REFERENCES

Beghdadi, M., Kouzi, K. & Ameur, A. (2019) New Design of an Optimized Synergetic Control by Hybrid BFO-PSO for PMSG Integrated in Wind Energy Conversion System Using Variable Step HCS Fuzzy MPPT. In: *International Conference in Artificial Intelligence in Renewable Energetic Systems*. pp. 30-40. doi: 10.1007/978-3-030-37207-1_4.

Blaabjerg, F., Dragicevic, T. & Davari, P. (2019) Applications of Power Electronics. *Electronics*. 8(4), 465. doi: 10.3390/electronics8040465.

Cimuca, G. (2005) Inertial energy storage system associated with generators wind turbines [*Système inertiel de stockage d'énergie associé à des générateurs éoliens]*. Thesis. Arts et Métiers ParisTech.

Cimuca, G., Breban, S., Radulescu, M., Saudemont, C. & Robyns, B. (2010) Design and Control Strategies of an Induction-Machine-Based Flywheel Energy Storage System Associated to a Variable-Speed Wind Generator. *IEEE Transactions on Energy Conversion*. 25(2), 526-534. doi: 10.1109/tec.2010.2045925.

Cimuca, G., Saudemont, C., Robyns, B. & Radulescu, M. (2006) Control and Performance Evaluation of a Flywheel Energy-Storage System Associated to a Variable-Speed Wind Generator. *IEEE Transactions on Industrial Electronics*. 53(4), 1074-1085. doi: 10.1109/tie.2006.878326.

Erdinc, O. & Uzunoglu, M. (2012) Optimum design of hybrid renewable energy systems: Overview of different approaches. *Renewable and Sustainable Energy Reviews*. 16(3), 1412-1425. doi: 10.1016/j.rser.2011.11.011.

Ghedamsi, K., Aouzellag, D. & Berkouk, E. (2008) Control of wind generator associated to a flywheel energy storage system. *Renewable Energy*. 33(9), 2145-2156. doi: 10.1016/j.renene.2007.12.009.

Guermit, H., Kouzi, K. & Bessedik, S. (2019) Novel design of an optimized synergetic control for dual stator induction motor. *COMPEL - The International Journal for Computation and Mathematics in Electrical and Electronic Engineering*. 38(6), 1828-1845. doi: 10.1108/compel-01-2019-0042.

Hebner, R., Beno, J. & Walls, A. (2002) Flywheel batteries come around again. *IEEE Spectrum*. 39(4), 46-51. doi: 10.1109/6.993788.

Kolesnikov, A., Veselov, G. & Kolesnikov, A. (2000) Modern applied control theory: synergetic approach in control theory. *TRTU*. pp. 4477-4479. Moscow, Taganrog.

Laribi, M., Ait Cheikh, M. S., Larbes, C., Essounbouli, N. & Hamzaoui, A. (2013) A sliding mode and synergetic control approaches applied to induction motor. In: *3rd International Conference on Systems and Control*, *29-31 October 2013, Algiers, Algeria*. NY, IEEE. pp. 212-217, doi: 10.1109/ICoSC.2013.6750861.

Lawrence, R., Craven, K. & Nichols, G. (2003) Flywheel UPS. *IEEE Industry Applications Magazine*. 9(3), 44-50. doi: 10.1109/mia.2003.1195682.

Lin, Z., Chen, Z., Wu, Q., Yang, S. & Meng, H. (2018) Coordinated pitch & torque control of large-scale wind turbine based on Pareto efficiency analysis. *Energy*. 147, 812-825. doi: 10.1016/j.energy.2018.01.055.

Mousa, H., Youssef, A. & Mohamed, E. (2019) Adaptive P&O MPPT algorithm based wind generation system using realistic wind fluctuations. *International Journal of Electrical Power & Energy Systems*. 112. 294-308. doi: 10.1016/j.ijepes.2019.04.038.

Nemsi, S., Belfedhal, S. A. & Barazane, L. (2016) Role of Flywheel Energy Storage System in Microgrid. *Journal of Engineering Research and Technology*. 3(3), 44-50.

Ni, J., Liu, C., Liu, K. & Pang, X. (2014) Variable speed synergetic control for chaotic oscillation in power system. *Nonlinear Dynamics*. 78(1), 681–690. doi: 10.1007/s11071-014-1468-0.

Retif, J. M. (2008) Vector control of permanent magnetic synchronous machine [Review of Vector control of permanent magnetic synchronous machine]. *Vector Control of Asynchronous and Synchronous Machines,* 19.

Sahin, A. (2004) Progress and recent trends in wind energy. *Progress in Energy and Combustion Science*. 30(5), 501-543. doi: 10.1016/j.pecs.2004.04.001.

Wang, J. & Bo, D. (2022) Adaptive fixed-time sensorless maximum power point tracking control scheme for DFIG wind energy conversion system. *International Journal of Electrical Power & Energy Systems.* 135, 107424. doi: 10.1016/j.ijepes.2021.107424.

Zhao, M. & Wang, T. (2018) A sliding mode and synergetic control approaches applied to Permanent Magnet Synchronous Motor. *Journal of Physics: Conference Series*. 1087, 042012. doi: 10.1088/1742-6596/1087/4/042012.

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