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Project Report
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Study & Control of a twin wind turbine system (SEREO)

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1 Introduction to SEREO

Provided with the system SEREO, which is nonlinear uncertain wind turbine system, the nacelle is equipped with a wind direction sensor without a turbine orientation actuator. Generally, the wind turbine systems with actuators has high maintenance. Without a wind direction sensor, it's not possible to orient turbine which does not have wind speed sensor. This wind turbine is a sensorless turbine relying only on wind directions.

Figure 1: SEREO STRUCTURE

The wind turbine system is represented with state vector as

$$x = [\psi \ \dot{\psi} \ i_{d1} \ i_{d2} \ i_{q1} \ i_{q2} \ \Omega_1 \ \Omega_2]'$$

where

- ψ-is the orientation of the wind turbine.
- i_{di},i_{qi}-are the stator currents.
- v_{di},v_{qi}-are the stator voltages.
- Ω_i-are the rotor speeds.

and the control input vector as

$$u = [v_{d1} \ v_{d2} \ v_{q1} \ v_{q2} \ ]'$$

one gets a nonlinear state system affine in the control input vector u reading as

$$\dot{x} = f(x) \ + \ g(x)u$$

Yaw angle dynamics is given as

$$\ddot{\psi} \ = \ -\frac{D_r}{K_r}\dot{\psi} \ + \ \frac{L}{K_r}[F_{d1} - F_{d2}]$$

and the drag force of the system as

$$F_{di} = \frac{1}{2}C_{di}(\lambda_i, \beta_i)\rho\pi R^2(Vcos(\psi - \alpha))$$

where

- D_r-is the frictional coefficient.
- K_r-is the inertia moment associated to yaw motion.
- L -is the length between the horizontal axis and the vertical axis.
- R - the radius of the wind turbine's blades.
- ρ-the air density, V -the wind velocity.
- β_i -the pitch angles of the blades.
- $C_{di}(\lambda_i, \beta_i)$ - the drag coefficients.

The electric model of three phase machines is written in (d,q) frame and reads as

$$\dot{i_{di}} = -\frac{Rs}{Ld}.id_i \;+\; p.\frac{Lq}{Ld}.iq_i.\Omega_i \;+\; \frac{1}{Ld}.v_{di}$$

$$\dot{i_{qi}} = -\frac{Rs}{Lq}.iq_i \;-\; p.\frac{Ld}{Lq}.id_i.\Omega_i \;-\; p.\frac{\phi_f}{Lq}.\Omega_i \;+\; \frac{1}{Lq}v_{qi}$$

Ld and Lq being inductance in (d,q)frame,Rs the stator resistance,p the number of pole pairs and ϕ_f the permanent magnet flux.The resultant electromagnetic torque of each machines is given by

$$\tau_i = p[(L_d - L_q)i_{d_i} \;+\; \phi_f]i_{q_i}$$

Then, the mechanical dynamics of each turbine reads as

$$\dot{\Omega}_i = \frac{1}{J}[\tau_{a_i}(V_w, \Omega_i, \beta_i) - \tau_{em_i}(i_{d_i}, i_{q_i})]$$

where J is the total inertia of the turbine, and τ_{a_i} the aerodynamic torque produced by the wind on the blades.

2 Control Objective

2.1 Torque oscillations reduction

The oscillations of the electromagnetic torque can be increasing the fatigues loads in the mechanical shaft of the wind turbine, and affecting the produced power.In order to avoid these drawbacks, one solution is to force

$$i_{d1} \to 0 \;\;, i_{d2} \to 0$$

where i_{d1} *and* i_{d2} are direct currents of turbine 1 and 2.

2.2 Power efficiency maximization

Power maximization is only obtained when turbines rotational velocity Ω is high and has a higher power coefficient C_{pi} . Eventually this is obtained only when the turbines face the wind. So evidently a reference torque has to be tracked, generally aerodynamics torque being tracked. We don't have any information regarding the wind velocity.

Tip-speed ratio λ_i is given by

$$\lambda_i = \frac{\Omega_i}{V_w} R \tag{1}$$

and aerodynamic torque τ_{ai} is given by

$$\tau_{ai} = \frac{1}{2} \frac{C_{pi}(\lambda_i, \beta_i)}{\lambda_i} \rho \pi R^3 V_w^2 \tag{2}$$

By solving equations (1) and (2) we obtain aerodynamics torque as

$$\tau_{ai} = \tau_{opt} = \tau_i * = \frac{\pi \rho R^5 C_{popt}}{2\lambda_{opt}^3} \Omega_i^2$$

where $C_{p_i}(\lambda_i, \beta_i)$, the power coefficient that defines the power conversion efficiency of the turbine.Then, the aerodynamic power extracted from the wind is

$$P_{a_i} = \frac{1}{2} C_{p_i}(\lambda_i, \beta_i) \rho \pi R^2 V_w^3$$

2.3 Yaw orientation

Given both the wind turbines are similar, the yaw dynamics can be approximated by,

$$\ddot{\psi} = -\frac{D_r}{K_r}\dot{\psi} + \frac{1}{2K_r} \rho \pi R^3 L c_1 V cos(\psi - \alpha)[\Omega_1 - \Omega_2] \tag{3}$$

To face the turbines to the wind, turbines must orient with change in wind, so it can generate more power.For the case when the wind turbine direction(ψ) is not oriented to the wind direction(α)i.e yaw error $e_\psi \neq 0 \neq \psi - \alpha$ the torque reference $\tau_i *$ are transiently detuned from their optimal value as follows:

$$\tau_1 * = \tau_{opt} - \Delta\tau *$$

$$\tau_2 * = \tau_{opt} + \Delta\tau *$$

The pink dashed line of Figure 2,in the neighborhood of $\tau_{opt} *$ the following linear approximation is valid

$$\Omega_i = -K v_w \tau_i * + \tau v_w \tag{4}$$

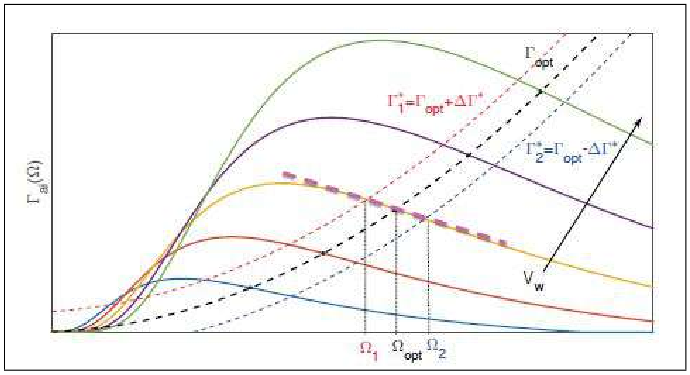


Figure 2: Aerodynamic torque τ_{ai} (N.m) versus rotation velocity Ω_i(rad/s), for increasing wind speed V_w (increasing sens from blue to green lines).

By substituting equation (4) in (3),gives

$$\begin{aligned}\ddot{\psi} \; &= \; -\frac{D_r}{K_r}\dot{\psi} \; + \; \frac{1}{2}\rho\pi R^3 L c_1 V_w K v_w(\tau_1 * - \tau_2 *) \\ &= \; -\frac{D_r}{K_r}\dot{\psi} \; - k(V_w)\Delta\tau *\end{aligned}$$

By designing an appropriate control law for $\Delta\tau*$, the second order system of yaw dynamics can be steered to zero yaw error $e_\psi = \; \psi - \alpha \; = 0$
.A solution consists of defining $\Delta\tau*$ as

$$\Delta\tau* = k_{\psi 0} e_\psi \; + \; k_{\psi 1}\dot{e}_\psi$$

In conclusion, the following torque references are given as,

$$\tau_1 * = \tau_{opt} - k_{\psi 0} e_\psi \; + \; k_{\psi 1}\dot{e}_\psi$$

$$\tau_2 * = \tau_{opt} + k_{\psi 0} e_\psi \; + \; k_{\psi 1}\dot{e}_\psi$$

Now the two control objectives for tacking torque references can be formalized as

$$\tau_1 \rightarrow \tau_1 * \; , \tau_2 \rightarrow \tau_2 *$$

3 Control Design

The control algorithm used is SUPER TWISTING ALGORITHM. A new controller has to be implemented. The proposed controller is based on the controller that reads as

$$\mathbf{u} \; = \; -k[\sigma]^\alpha$$

The objective is to vary α according to the following law

$$\alpha \; = \; max\left(-\beta\frac{|\sigma|}{|\sigma| \; + \; \varepsilon} \; + 1, \; 0\right), \;\; \alpha \in [0,1] \;\; with \;\; \beta > 1 \;\; and \;\; \varepsilon > 0$$

β and ε are linked to the accuracy of the controller.Therefore, if β increases or ε decreases,the accuracy of the closed loop system increases.However, increasing β or decreasing ε leads to lower values of α on average and therefore a higher energy consumption. So one shall tune these two parameters wisely as to achieve the required trade-off between accuracy and energy consumption. When the value of σ increases in absolute value, this means that the accuracy of the closed loop system is reduced.Therefore, the value of α automatically decreases in order to increase the robustness of the system and increase the accuracy.

When the accuracy of closed loop is reduced, then the value of α decreases in order to increase system accuracy and robustness, but when the system is accurate , the value of α automatically increases in order to reduce the power consumption.

As our control objectives are defined now, the sliding variables of relative degree 1 of a super twisting algorithm are defined as

$$\begin{bmatrix} id_1 \\ id_2 \\ \tau_1 - \tau_1* \\ \tau_2 - \tau_2* \end{bmatrix}$$

The relative degree vector of system with output and versus the input is [2,1,2,1]',then one gets

$$\begin{bmatrix} \dot{\sigma}_{id_1} \\ \dot{\sigma}_{id_2} \\ \dot{\sigma}_{\tau_1} \\ \dot{\sigma}_{\tau_2} \end{bmatrix} = A \ + \ B. \begin{bmatrix} v_{d1} \\ v_{d2} \\ v_{q1} \\ v_{q2} \end{bmatrix}$$

where $\begin{bmatrix} v_{d1} \\ v_{d2} \\ v_{q1} \\ v_{q2} \end{bmatrix}$ is our input vector. So the new control input vector is defined as

$$v = B^{-1}[-A \ + \ w]$$

where w is new input. A and B^{-1} matrix is given by

$$A = \begin{bmatrix} -\frac{Rs}{Ld}.id_1 \ + \ p.\frac{Lq}{Ld}.iq_1.\Omega_1 \\ -\frac{Rs}{Ld}.id_2 \ + \ p.\frac{Lq}{Ld}.iq_2.\Omega_2 \\ p._f.(-\frac{Rs}{Lq}.iq_1 \ + \ p.\frac{Lq}{Ld}.id_1.\Omega_1 \ - \ p.\frac{f}{Lq}.\Omega_1) \ + \ p(Ld - Lq).iq_1.(-\frac{Rs}{Ld}.id_1 \ + \ p.\frac{Lq}{Ld}.iq_1.\Omega_1)... \\ .... \ + \ p(Ld - Lq).id_1.(-\frac{Rs}{Lq}.iq_1 \ - \ p.\frac{Ld}{Lq}.id_1.\Omega_1 \ + \ \dot{\tau_1}*) \\ p._f.(-\frac{Rs}{Lq}.iq_2 \ + \ p.\frac{Lq}{Ld}.id_2.\Omega_2 \ - \ p.\frac{f}{Lq}.\Omega_2) \ + \ p(Ld - Lq).iq_2.(-\frac{Rs}{Ld}.id_2 \ + \ p.\frac{Lq}{Ld}.iq_2.\Omega_2)... \\ .... \ + \ p(Ld - Lq).id_2.(-\frac{Rs}{Lq}.iq_2 \ - \ p.\frac{Ld}{Lq}.id_2.\Omega_2 \ + \ \dot{\tau_2}*) \end{bmatrix}$$

$$B^{-1} = \begin{bmatrix} Ld & 0 & 0 & 0 \\ 0 & 0 & Ld & 0 \\ \frac{Ld}{p(Ld-Lq)iq_1} & \frac{LdLq}{Ldp_f(Ld-Lq)id_1} & 0 & 0 \\ 0 & 0 & \frac{Ld}{p(Ld-Lq)iq_2} & \frac{LdLq}{Ldp_f(Ld-Lq)id_2} \end{bmatrix}$$

There are three types of controller whose results must be evaluated and compared.In this section the new input for all types of controller are defined.

3.1 Sliding Mode Controller

In sliding mode the new input to the system is defined as

$$w = \begin{bmatrix} -k_{id_1} sign(\sigma_{id_1}) \\ -k_{id_2} sign(\sigma_{id_2}) \\ -k_{\tau_1} sign(\sigma_{\tau_1}) \\ -k_{\tau_2} sign(\sigma_{\tau_2}) \end{bmatrix}$$

Though the gains for sliding variable of $\sigma_i d_1$, $\sigma_i d_2$ and σ_{τ_1} , σ_{τ_2} are same, we define two different gain constants, because in condition where we have same wind we can have same gains, but once the wind changes and angular speed of rotor of two turbine changes we need to tune them independently.

3.2 α-controller(new controller)

The new implemented controller reads the input as

$$w = \begin{bmatrix} -k_{id_1} \left|\sigma_{id_1}\right|^{\alpha} sign(\sigma_{id_1}) \\ -k_{id_2} \left|\sigma_{id_2}\right|^{\alpha} sign(\sigma_{id_2}) \\ -k_{\tau_1} \left|\sigma_{\tau_1}\right|^{\alpha} sign(\sigma_{\tau_1}) \\ -k_{\tau_2} \left|\sigma_{\tau_2}\right|^{\alpha} sign(\sigma_{\tau_2}) \end{bmatrix}$$

where α varies according to the following law

$$\alpha = max\left(-\beta\frac{|\sigma|}{|\sigma| + \varepsilon} + 1, 0\right), \ \ \alpha \in [0,1] \ with \ \beta > 1 \ and \ \varepsilon > 0$$

3.3 linear control of sliding variable

In the previous case when $\alpha = 1$, the input is read as

$$w = \begin{bmatrix} -k_{id_1} \left|\sigma_{id_1}\right| sign(\sigma_{id_1}) \\ -k_{id_2} \left|\sigma_{id_2}\right| sign(\sigma_{id_2}) \\ -k_{\tau_1} \left|\sigma_{\tau_1}\right| sign(\sigma_{\tau_1}) \\ -k_{\tau_2} \left|\sigma_{\tau_2}\right| sign(\sigma_{\tau_2}) \end{bmatrix}$$

Now the system is read as

$$\begin{bmatrix} \dot{\sigma}_{id_1} \\ \dot{\sigma}_{id_2} \\ \dot{\sigma}_{\tau_1} \\ \dot{\sigma}_{\tau_2} \end{bmatrix} = \begin{bmatrix} -k_{id_1}.\sigma_{id_1} \\ -k_{id_2}.\sigma_{id_2} \\ -k_{\tau_1}.\sigma_{\tau_1} \\ -k_{\tau_2}.\sigma_{\tau_2} \end{bmatrix}$$

4 Evaluation of controllers

The controllers are evaluated according to the objectives accomplishment. Objectives being reducing the oscillation of electromagnetic torque and power maximization. Oscillations are evaluated, how far they are deviating from the mean values.So we choose standard deviation of torque as one of the evaluation tool and to check for maximum power i.e the orientation of the turbine to the wind can also be evaluated.

In order to evaluate the robustness of the closed-loop system, and its behavior with noises, some errors have been assumed

- The resistances R are known with an error equal to 20% of the nominal value.
- the direct inductance's Ld are known with an error equal to -15% of the nominal value.

The tuned gains for the linear controller are

$$k_{id_i} = 10$$

$$k_{\tau_i} = 1000$$

The tuned gains for the α controller and Sliding mode controller are

$$k_{id_i} = 1000$$

$$k_{\tau_i} = 100000$$

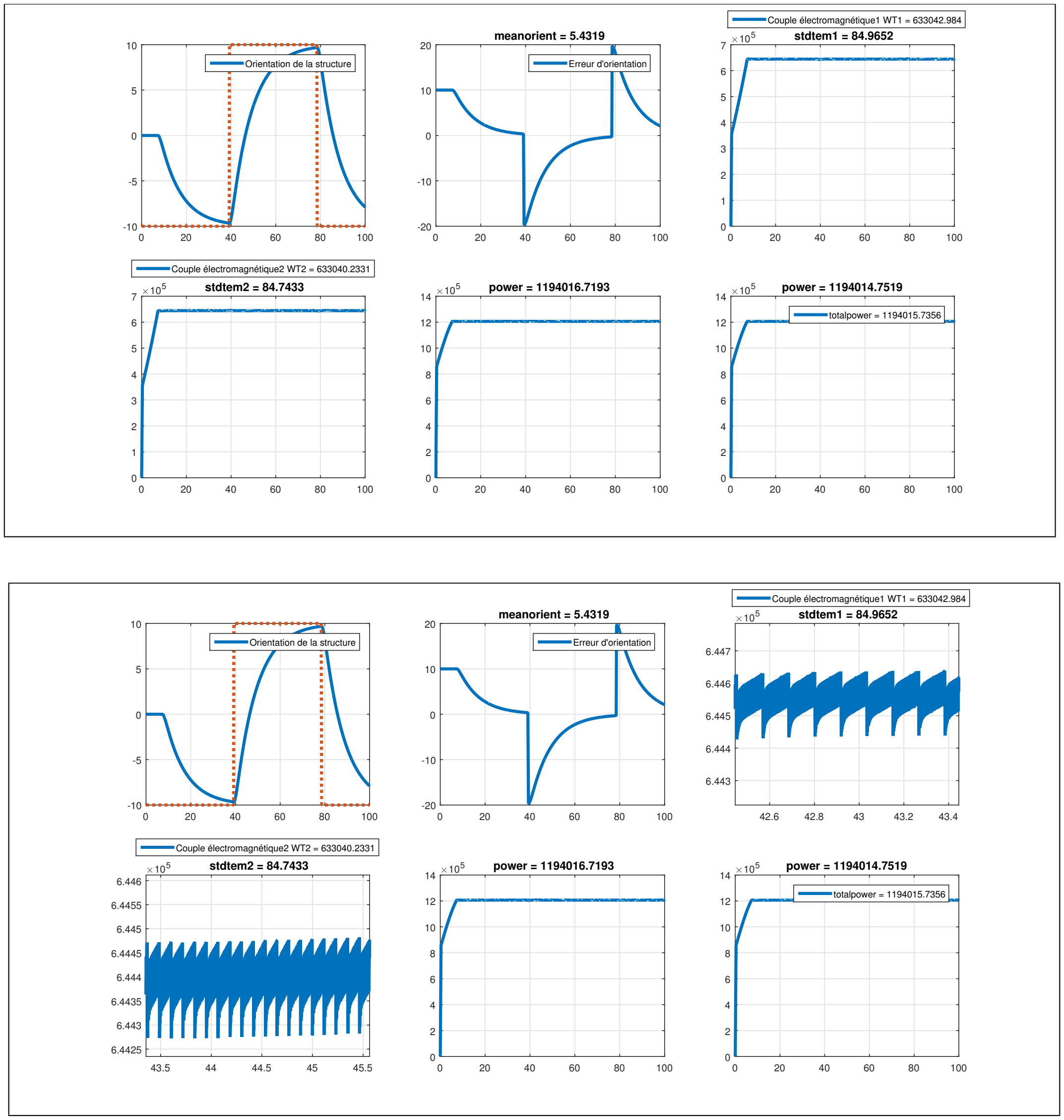


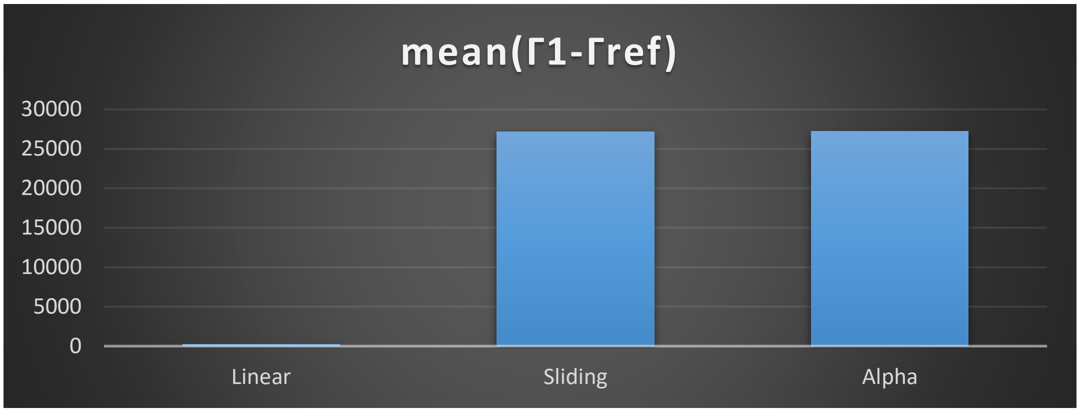
Figure 3: Plots for SM controller

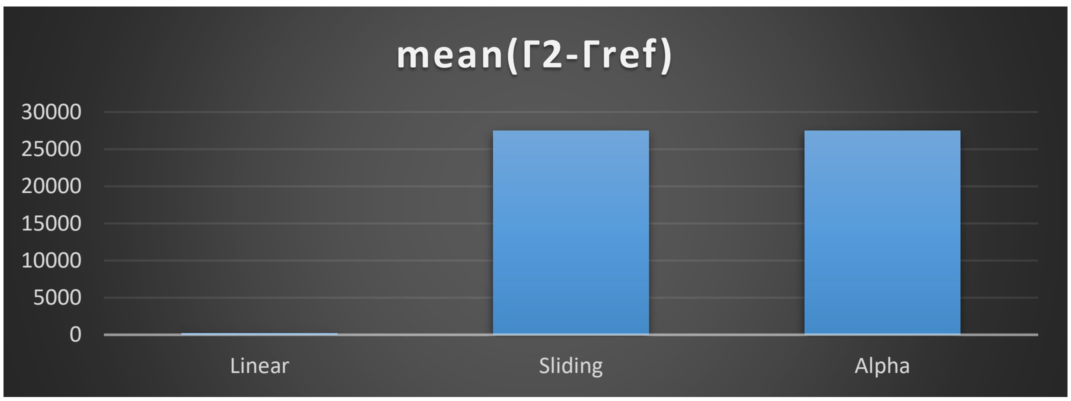
Table 1: For $\beta = 4, \varepsilon = 100$ and $\beta = 5, \varepsilon = 100$

Evaluation tools	$\alpha = 0.00035$	$\alpha = 0.0002$
e_ψ	4.8055	4.7774
std.deviations τ_1	545.0277	536.9636
std.deviations τ_2	544.3571	537.6337
τ_1	643365.223	643361.1196
τ_2	643362.6827	643358.5256
Power	1206353.1070	1206349.40
$\tau_1 - \tau_1*$	3309.9413	3306.7226
$\tau_2 - \tau_2*$	3336.3635	3330.3196

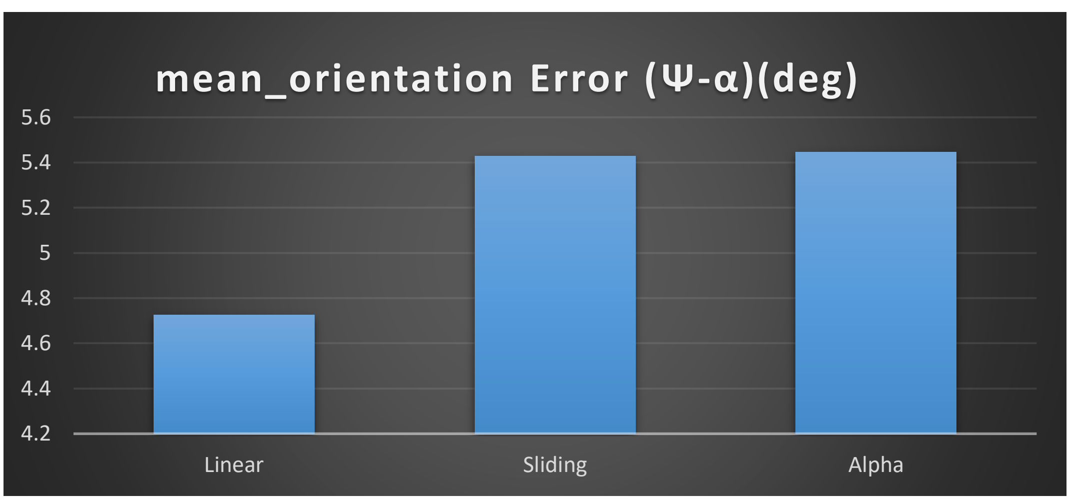
From the above table, with the increase in β there is decreases in α which increases the system accuracy, the system accuracy is defined by our sliding variables $\tau_1 - \tau_1*$ and $\tau_2 - \tau_2*$, but decrease in α also increases power consumption, so we get lesser power, so there is a trade-off between accuracy and power consumption.

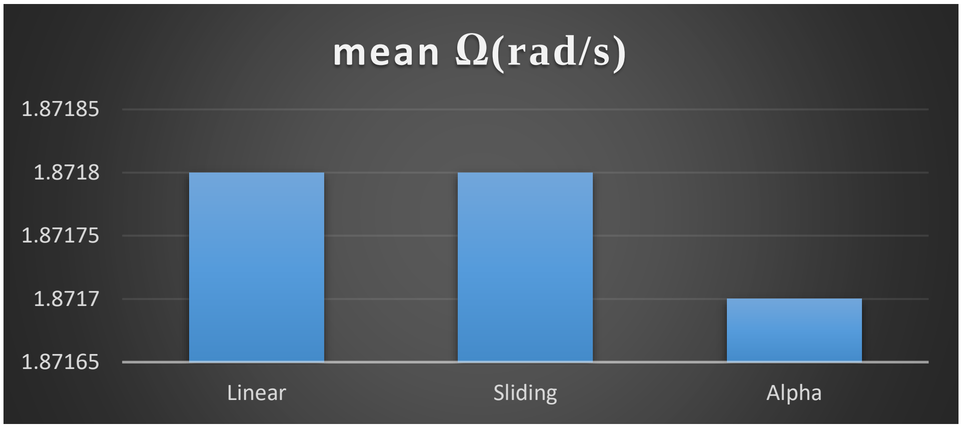
The below figures shows the comparison between each three controllers.



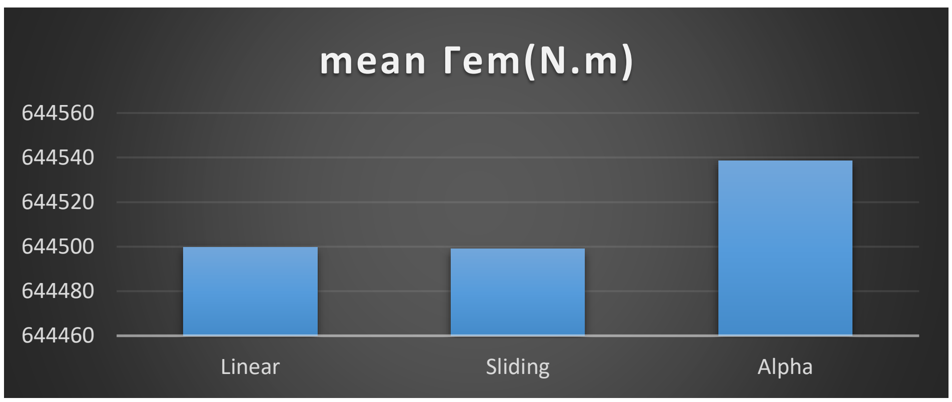


Mean(Γ-Γref) is the sliding variable, from the linear controller the tracking to Γref* is good and generates more power, which is our objective. Similarly, the mean orientation in linear controllers is good, which means its facing the wind better than the other controller.

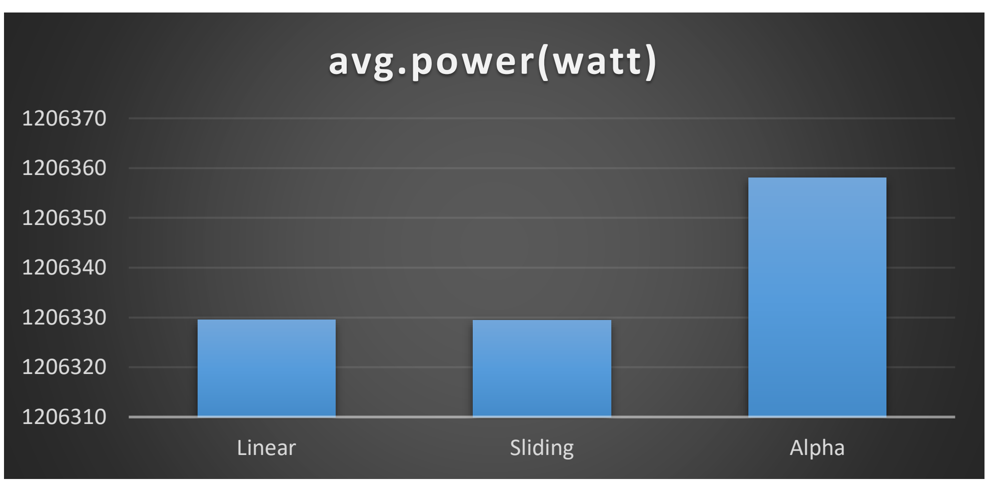


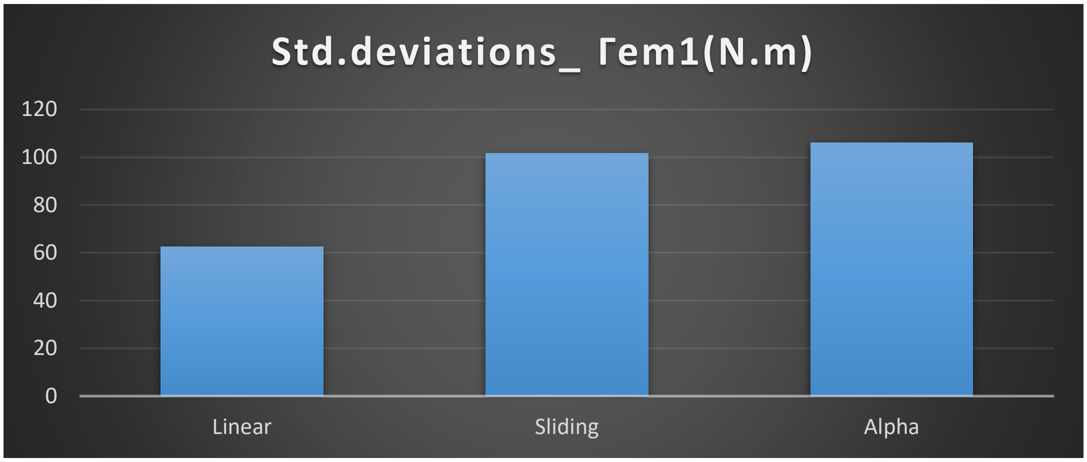


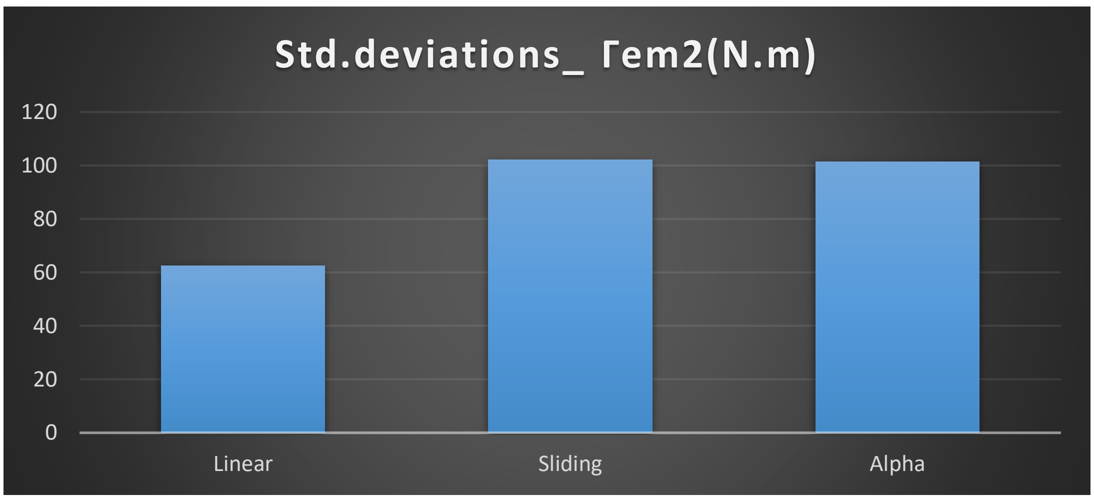
The rotational velocity increases in linear case, because of orientation of turbine with wind is better.



Torque increase with small amount with larger gains in alpha controller, since sliding and alpha has same gains, alpha controller tuned with β and ε parameters, reducing the power consumption.







Standard deviations are the oscillations deviation from the mean torque, in linear controller the oscillations of torque have been reduced. From the simulations and analyzing the plots we conclude that linear controller is the better one.

5 Tuning with symmetric wind (s.w):

As we have found the Linear Controller to be the best controller, now we shall study the robustness of this controller. We will tune the following parameters in order to check how sensitive the system is to the change in these parameters. For this tuning we shall maintain same wind on both the turbines.

5.1 Resistance and Inductance (R & L)

The Resistance's R of the SEREO system are known i.e. an error equal to +20% of the nominal value. But we are going to study the behaviour of the system by having no errors in order to know how sensitive the system is to the Resistance's.

The Inductance's L of the SEREO system are known i.e. an error equal to -15% of the nominal value. But we are going to study the behaviour of the system by having no errors in order to know how sensitive the system is to the Inductance's.

5.2 Inertia (J)

The Inertia J of the SEREO system are known i.e. an error equal to +10% of the nominal value. But we are going to study the behaviour of the system by increasing the errors again by ±10% & ±50% to know how sensitive the system is to Inertia.

5.3 Drag Force (F_{d1} & F_{d2})

Even drag force can be tuned to study the SEREO system as it is produced by acting on the generator torques. We are going to introduce an error of ±10% & ±50% for both the turbines (F_{d1} & F_{d2}) and study the behaviour of the system.

5.4 Aero-dynamic Torque (Υ_{a1} & Υ_{a2})

Even aero-dynamic torque can be tuned to study the SEREO system. We are going to introduce an error of ±10% & ±50% for both the turbines (Υ_{a1} & Υ_{a2}) and study the behaviour of the system.

5.5 Flux (F_i)

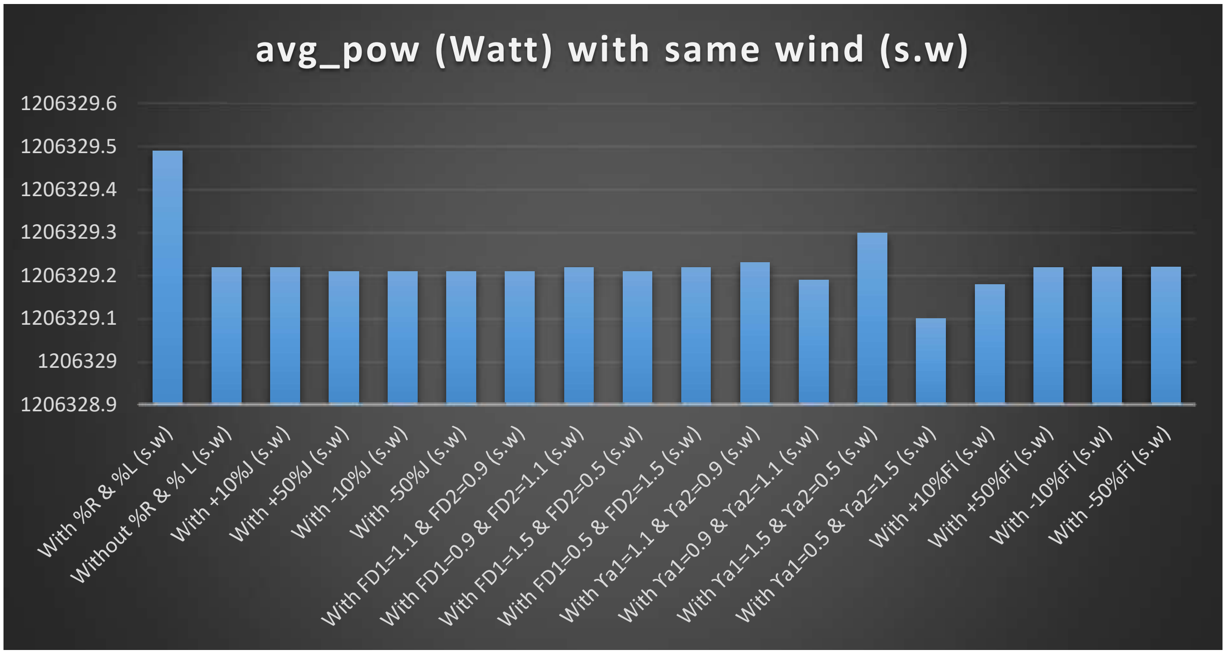
The Flux of the SEREO system are known and fixed as we are using permanent magnets. But we are going to study the behaviour of the system by increasing the errors again by ±10% & ±50% to know how sensitive the system is to Flux.

6 Plots with symmetric wind (s.w):

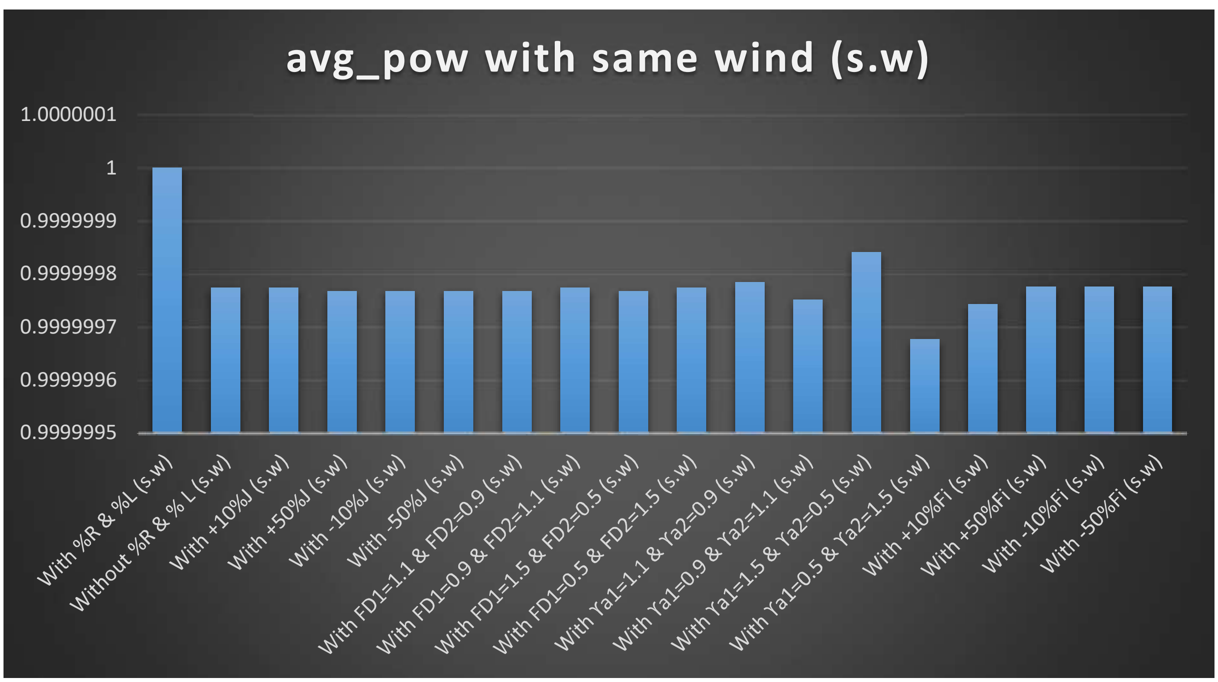
We have tuned all the parameters accordingly and to check how robust or how sensitive the SEREO system is for the changes based on its performance in terms of the following.

For all the comparisons we shall fix the controller with the known errors for nominal resistance and inductance as standard, to compare with and without errors of different parameters.

6.1 Average-Power (P)

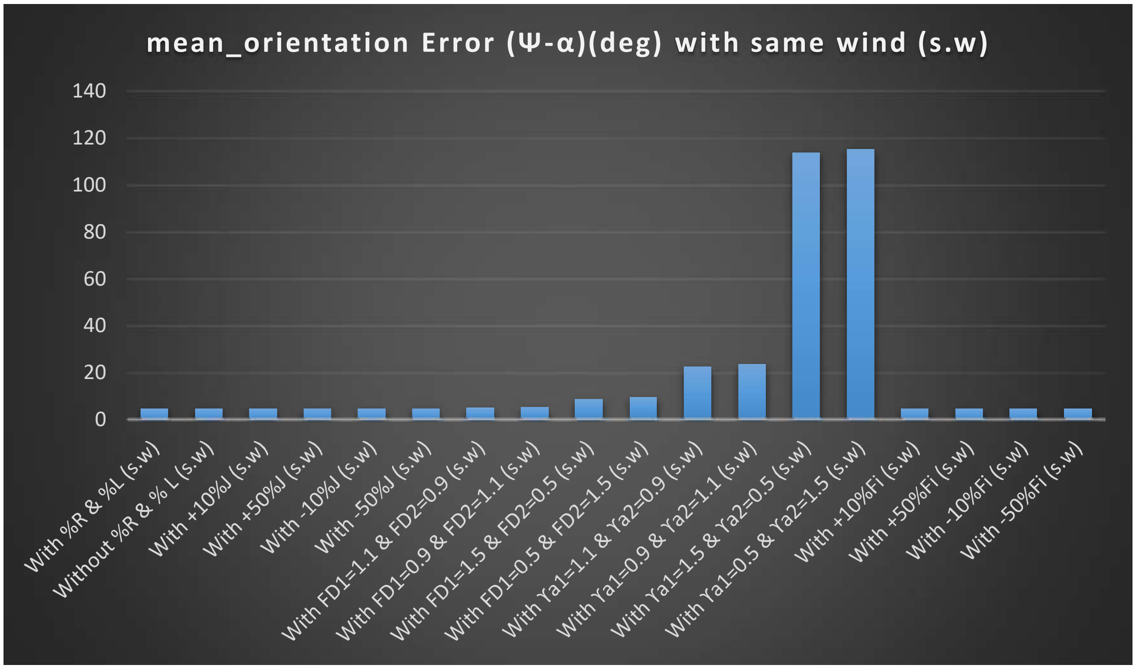


From the above plot we can say that the controller with the known errors for nominal resistance and inductance has high performance w.r.t power. But the system is so robust that any change in any parameters doesn't affect the performance much comparatively.

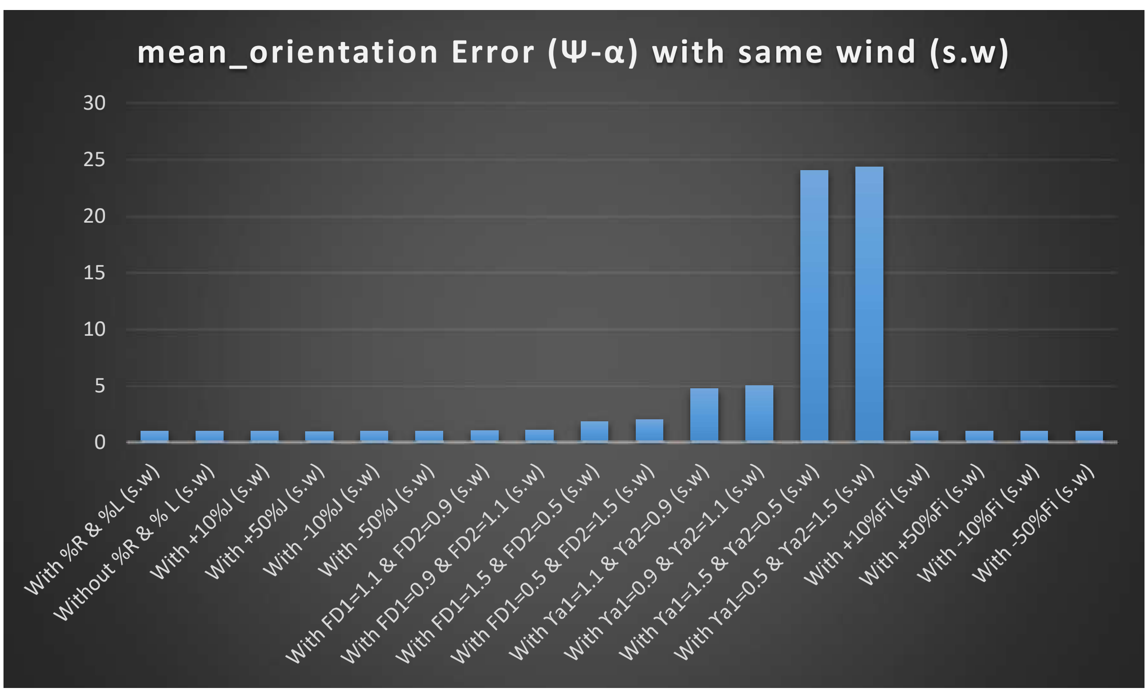


As we have said above that the controller with the known errors for nominal resistance and inductance as standard, a comparison plot is shown above.

6.2 Mean-Orientation Error (Ψ-α)

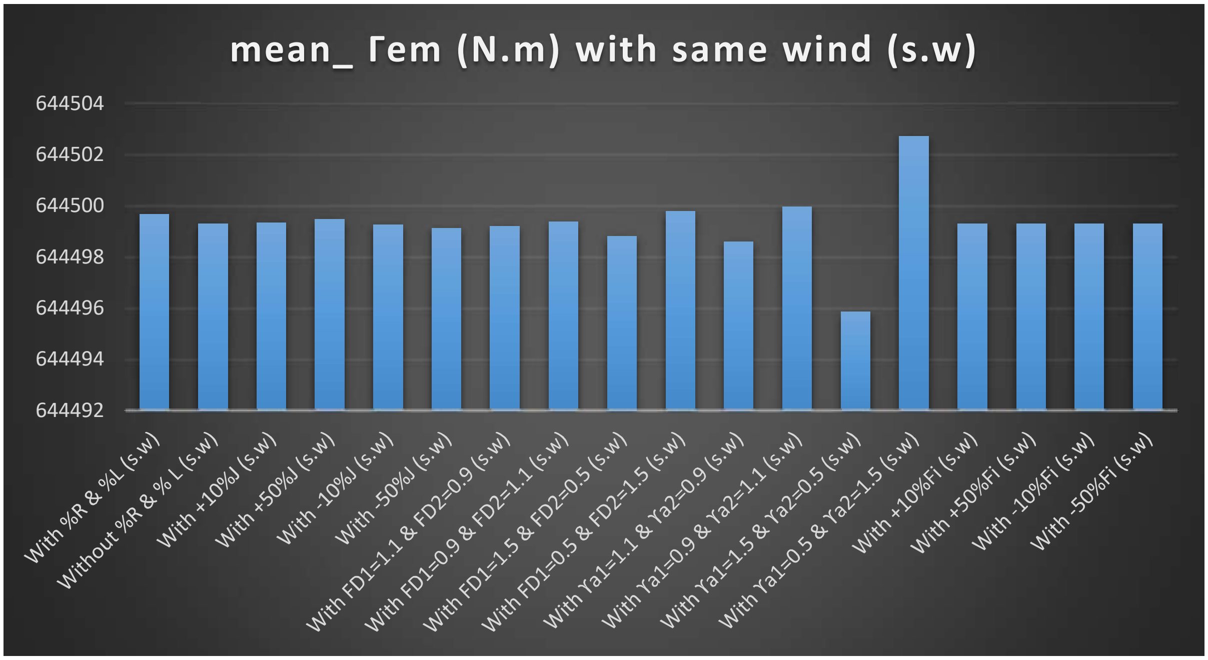


From the above plot we can say that the controller with the known errors for nominal resistance and inductance has low orientation error i.e. Turbines are facing the wind. But we can see that a small change in the drag force or the aero-dynamic torque results in increase of error. And for any other change in parameter doesn't really affect the system much.

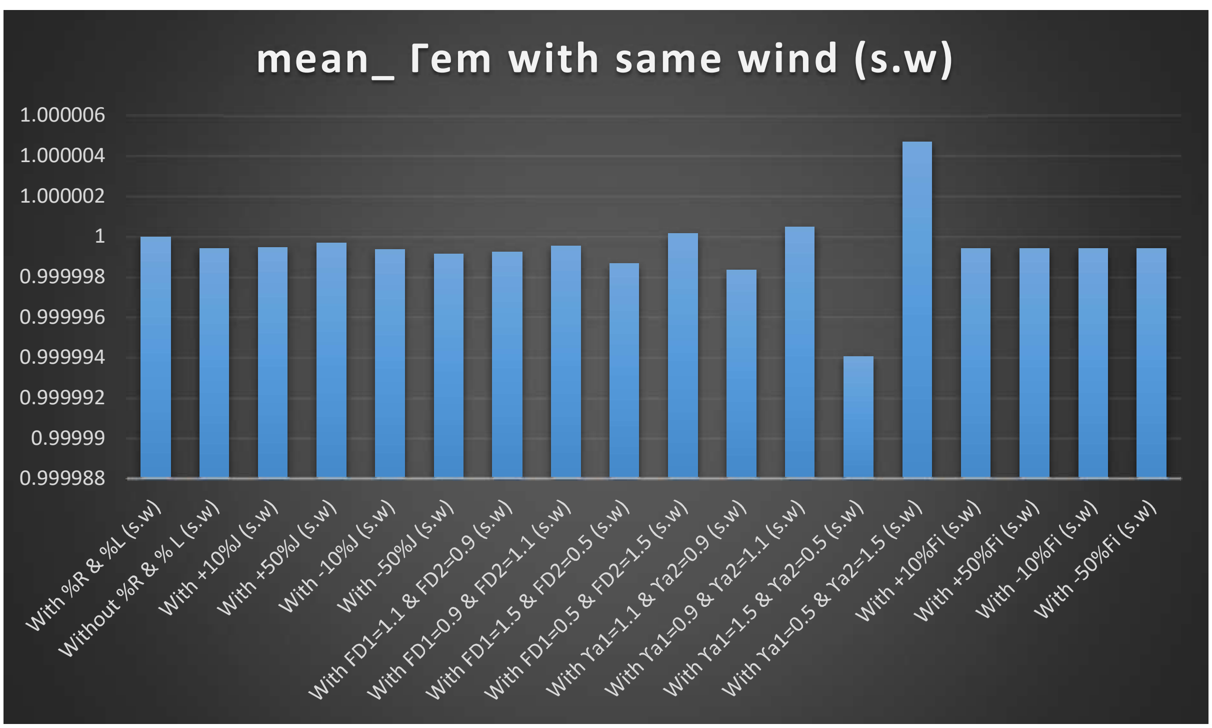


As we have said above that the controller with the known errors for nominal resistance and inductance as standard, a comparison plot is shown above.

6.3 Mean-Electro-Magnetic Torque (Γ_{em})

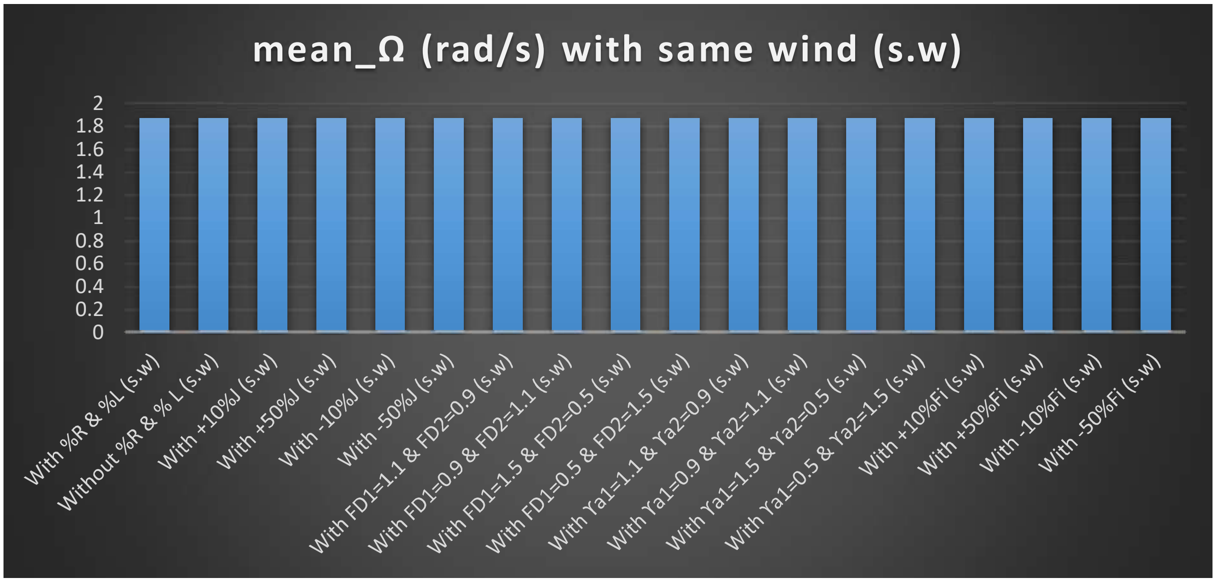


From the above plot we can say that the controller with the known errors for nominal resistance and inductance has optimum performance w.r.t electro-magnetic torque produced. But the system is so robust that any change in any parameters doesn't affect the performance much comparatively.

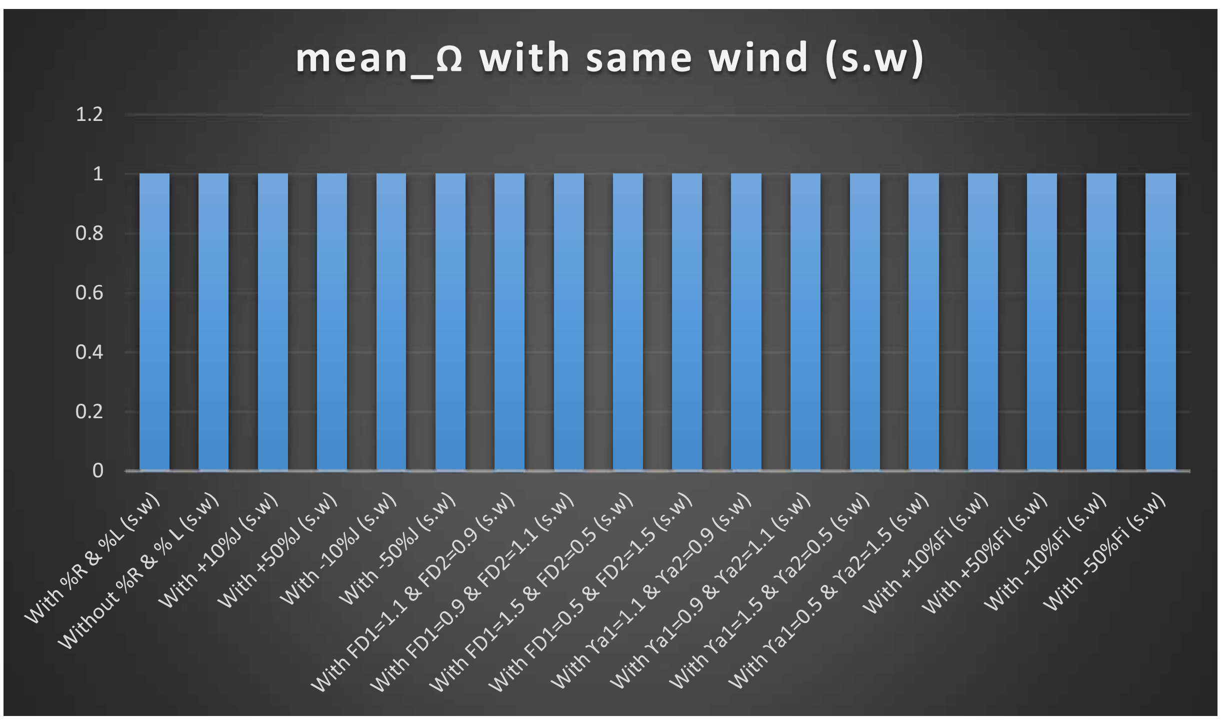


As we have said above that the controller with the known errors for nominal resistance and inductance as standard, a comparison plot is shown above.

6.4 Mean-Angular Velocity (Ω)



From the above plot we can say that the controller has no affect with the angular velocity by any change in parameters i.e. the rotation of the blades remains the same throughout. Hence the system is robust.



As we have said above that the controller with the known errors for nominal resistance and inductance as standard, a comparison plot is shown above.

7 Tuning with asymmetric wind (d.w):

For this tuning we shall have different wind on the turbines. We will tune the following parameters in order to check how sensitive the system is to the change in these parameters and study the robustness of this controller.

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The Inductance's L of the SEREO system are known i.e. an error equal to -15% of the nominal value. But we are going to study the behaviour of the system by having no errors in order to know how sensitive the system is to the Inductance's.

7.2 Inertia (J)

The Inertia J of the SEREO system are known i.e. an error equal to +10% of the nominal value. But we are going to study the behaviour of the system by increasing the errors again by ±10% & ±50% to know how sensitive the system is to Inertia.

7.3 Drag Force (F_{d1} & F_{d2})

Even drag force can be tuned to study the SEREO system as it is produced by acting on the generator torques. We are going to introduce an error of ±10% & ±50% for both the turbines (F_{d1} & F_{d2}) and study the behaviour of the system.

7.4 Aero-dynamic Torque (Υ_{a1} & Υ_{a2})

Even aero-dynamic torque can be tuned to study the SEREO system. We are going to introduce an error of ±10% & ±50% for both the turbines (Υ_{a1} & Υ_{a2}) and study the behaviour of the system.

7.5 Flux (F_i)

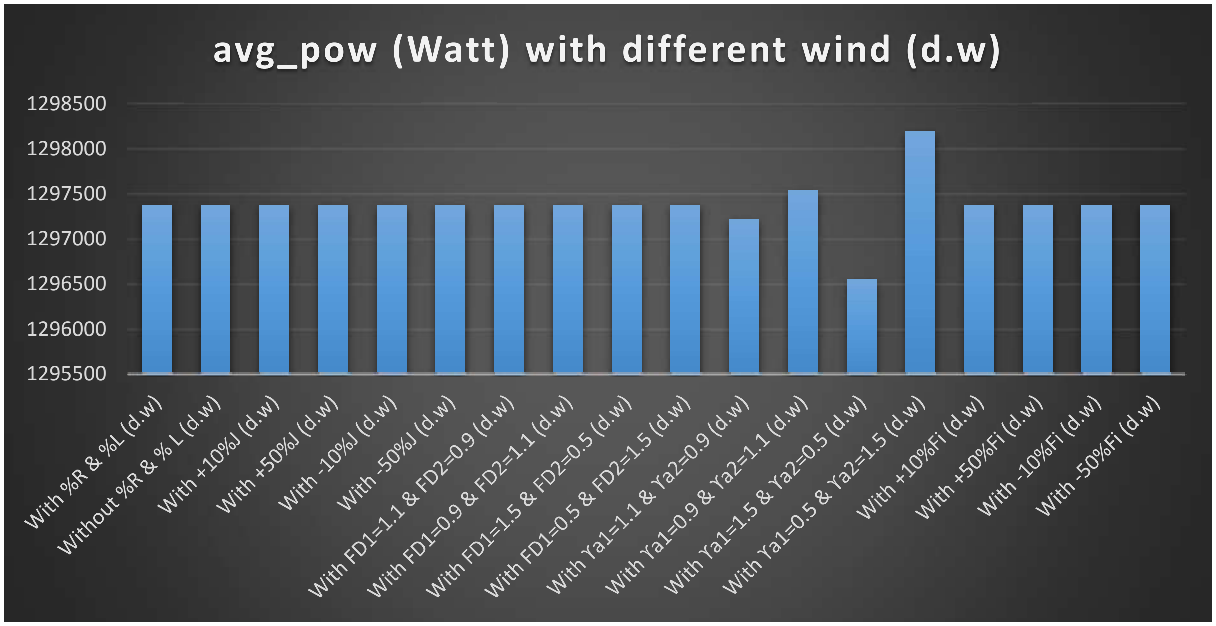
The Flux of the SEREO system are known and fixed as we are using permanent magnets. But we are going to study the behaviour of the system by increasing the errors again by ±10% & ±50% to know how sensitive the system is to Flux.

8 Plots with asymmetric wind (d.w):

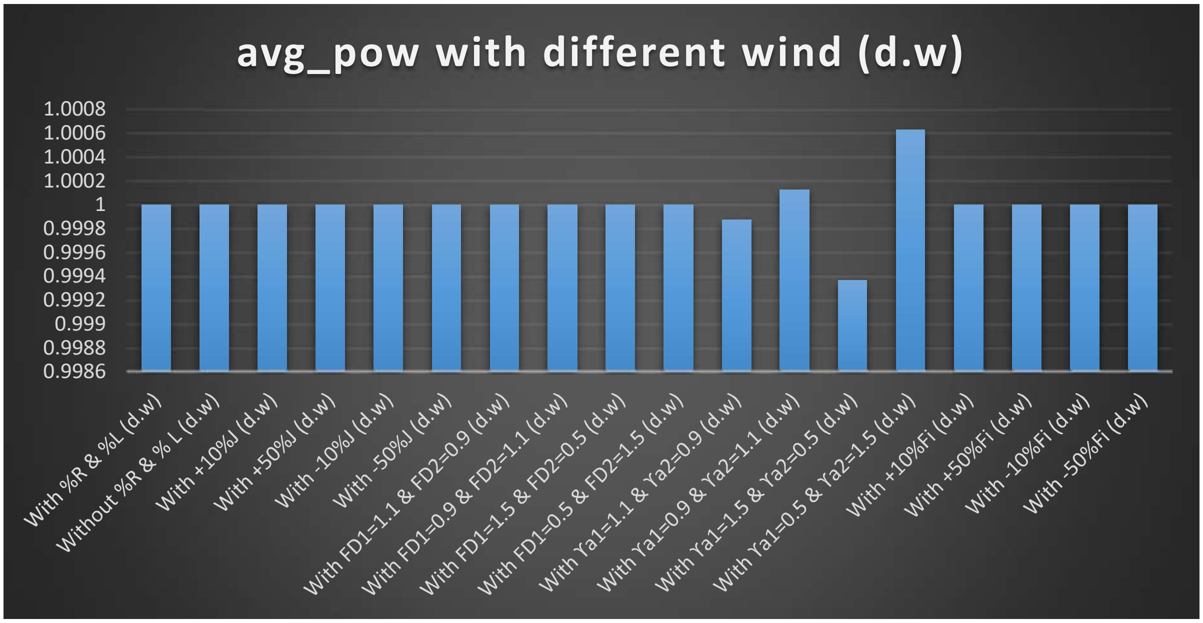
We have tuned all the parameters accordingly and to check how robust or how sensitive the SEREO system is for the changes based on its performance in terms of the following.

For all the comparisons we shall fix the controller with the known errors for nominal resistance and inductance as standard, to compare with and without errors of different parameters.

8.1 Average-Power (P)

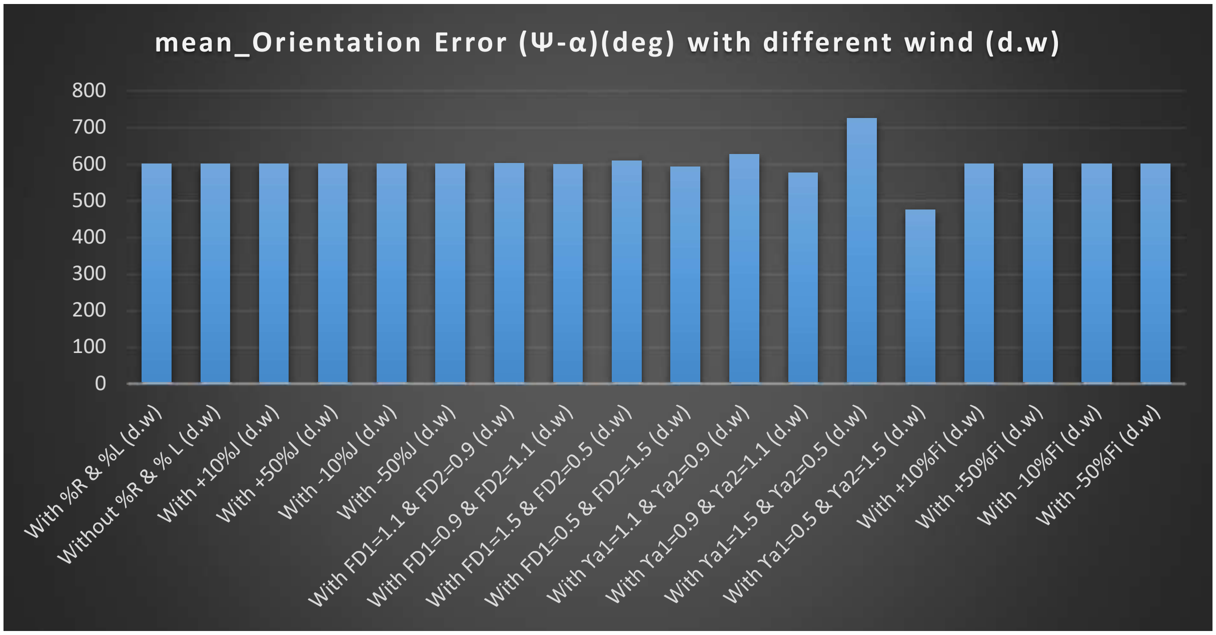


From the above plot we can say that the controller with the known errors for nominal resistance and inductance has optimum performance w.r.t power. BUt the system is so robust that any change in any parameters doesn't affect the performance much comparatively.

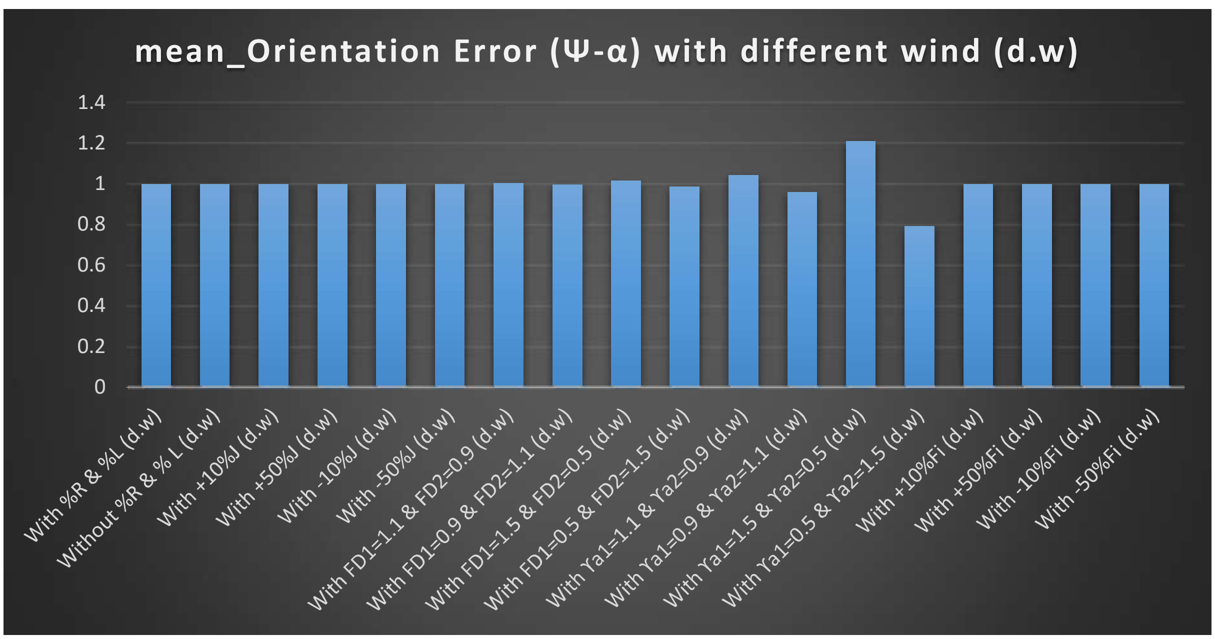


As we have said above that the controller with the known errors for nominal resistance and inductance as standard, a comparison plot is shown above.

8.2 Mean-Orientation Error (Ψ-α)

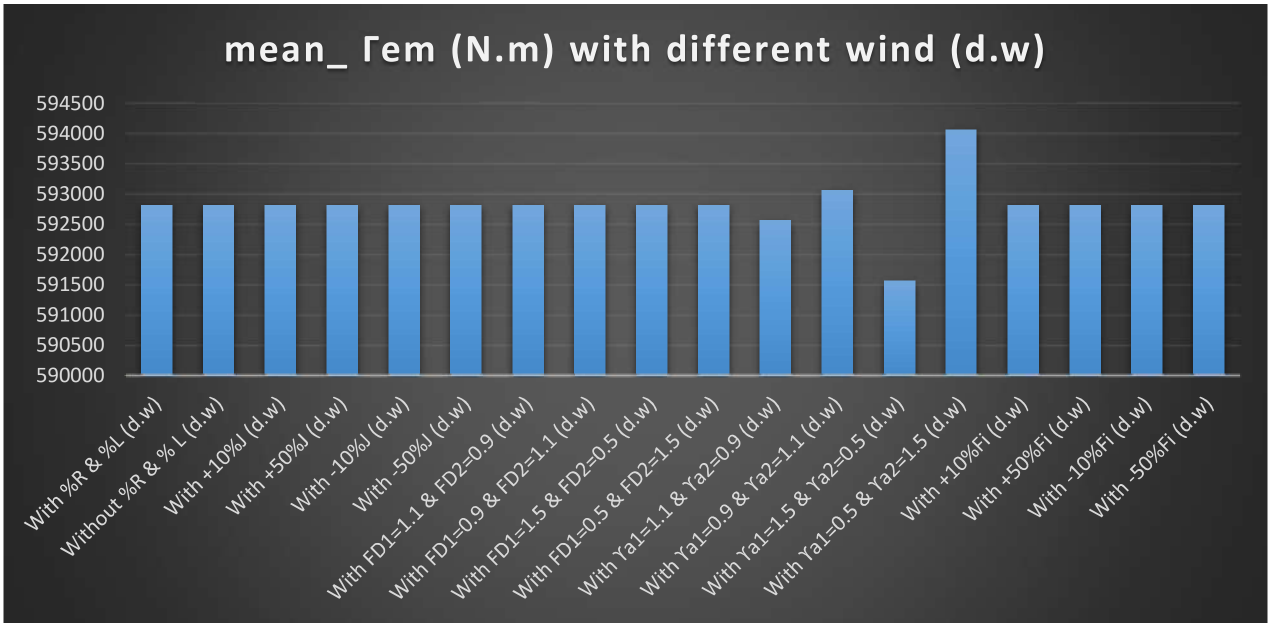


From the above plot we can say that the controller with the known errors for nominal resistance and inductance has orientation error i.e. Turbines facing the wind (600 = 60°) as we are using different winds. But for any other change in parameter doesn't really affect the system much.

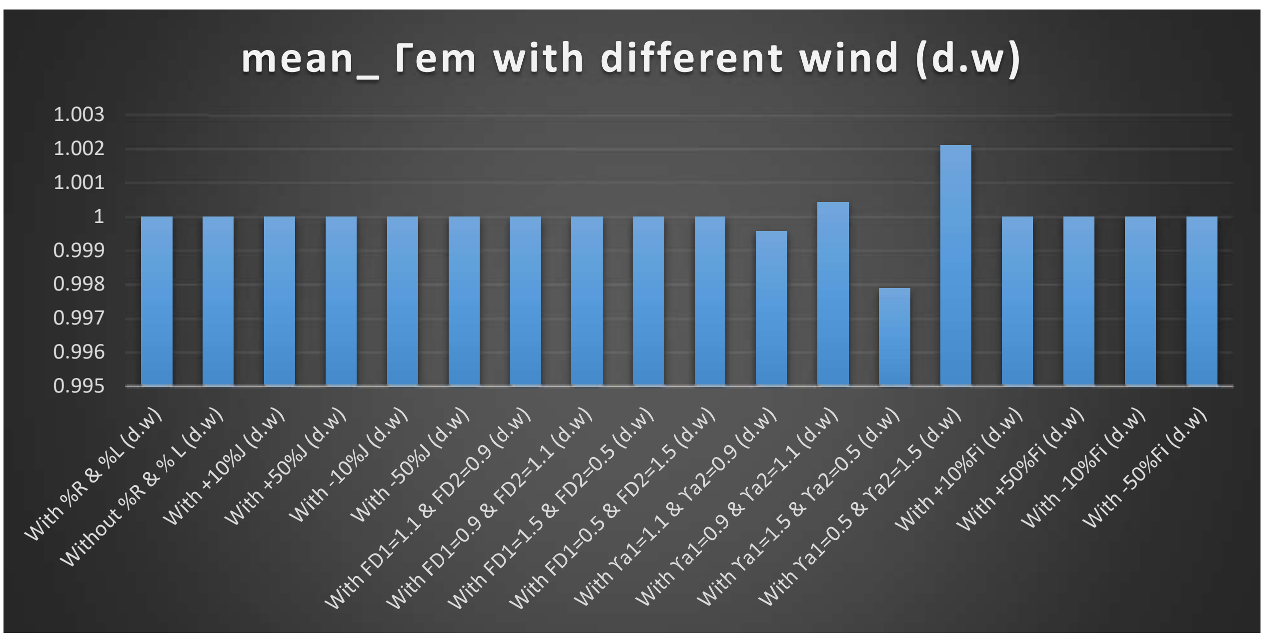


As we have said above that the controller with the known errors for nominal resistance and inductance as standard, a comparison plot is shown above.

8.3 Mean-Electro-Magnetic Torque (Γ_{em})

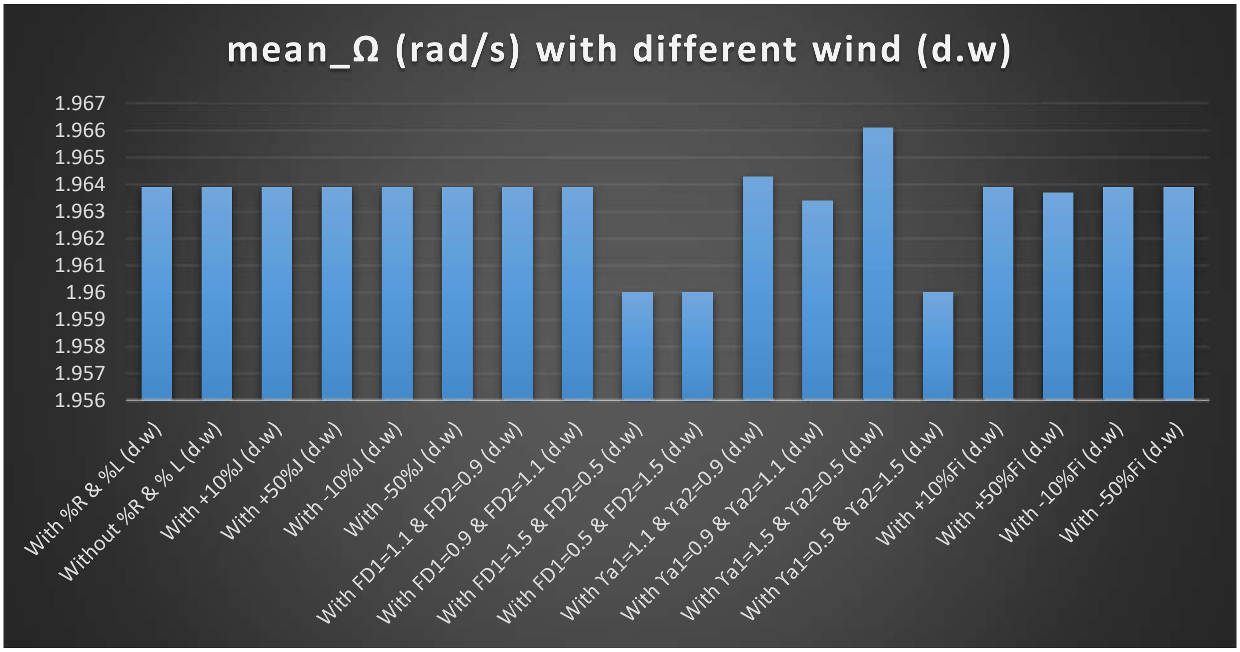


From the above plot we can say that the controller with the known errors for nominal resistance and inductance has optimum performance w.r.t electro-magnetic torque produced, except a slight variation when an error is introduced in aero-dynamic torque. But the system is so robust that any change in any parameters doesn't affect the performance much comparatively.

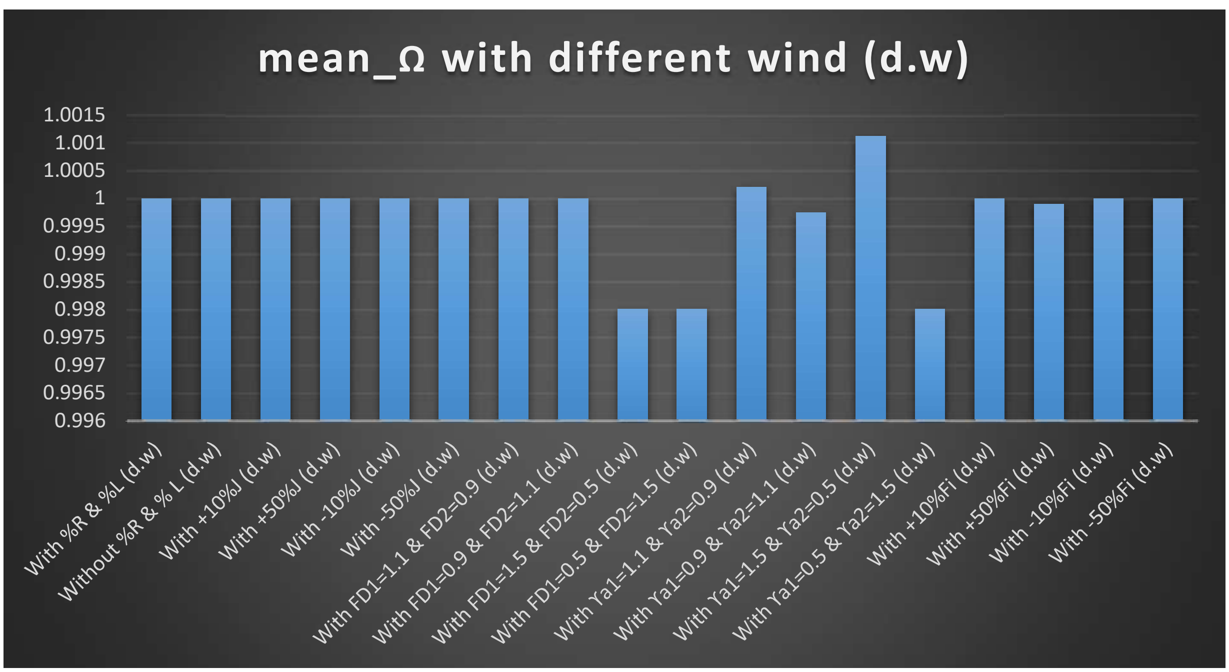


As we have said above that the controller with the known errors for nominal resistance and inductance as standard, a comparison plot is shown above.

8.4 Mean-Angular Velocity (Ω)



From the above plot we can say that the controller with the known errors for nominal resistance and inductance has optimum performance w.r.t angular velocity, except a slight variation when an error is introduced in aero-dynamic torque & drag force. But the system is so robust that any change in any other parameters doesn't affect the performance much comparatively.



As we have said above that the controller with the known errors for nominal resistance and inductance as standard, a comparison plot is shown above.

9 Conclusion:

The controller was chosen according to the performance. The controller is robust and accurate for the wind velocity between 9 m/s and 12 m/s. The robustness was evaluated by increasing different errors and evaluating performance. From the following plots it's clear that $F_{d1}=F_{d2}$ for same winds and change of winds.

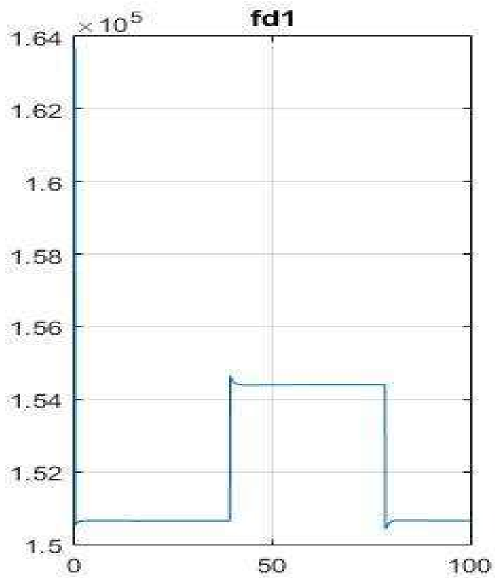


Fig showing F_{d1} i.e. for 10 m/s.

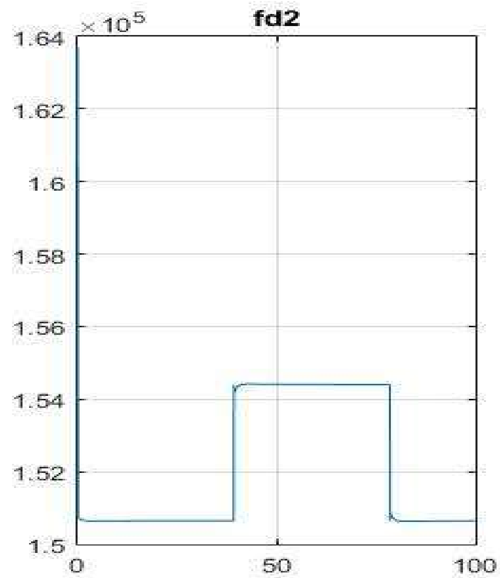


Fig showing F_{d2} i.e. for 10 m/s.

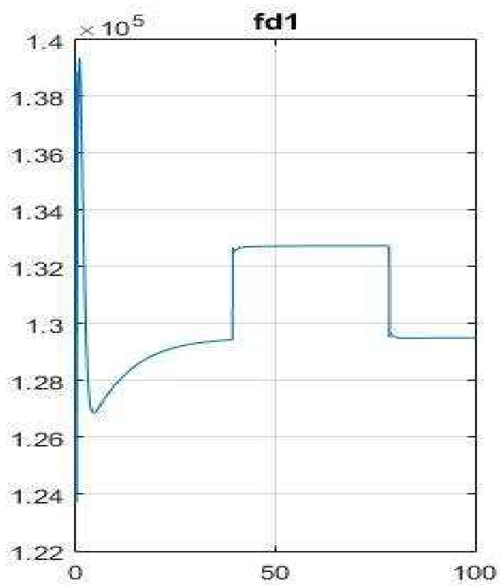


Fig showing F_{d1} i.e. for 9 m/s.

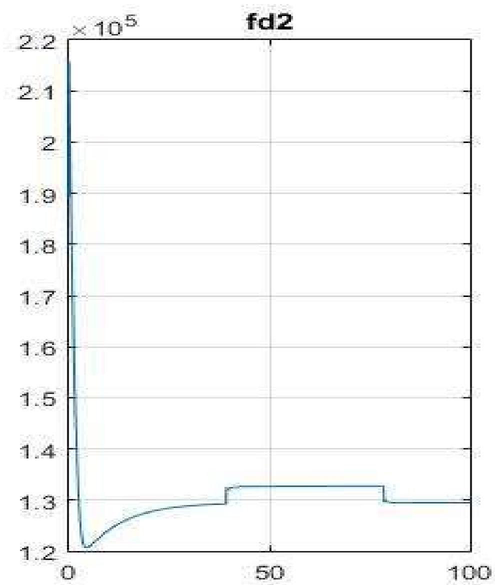


Fig showing F_{d2} i.e. for 12 m/s.

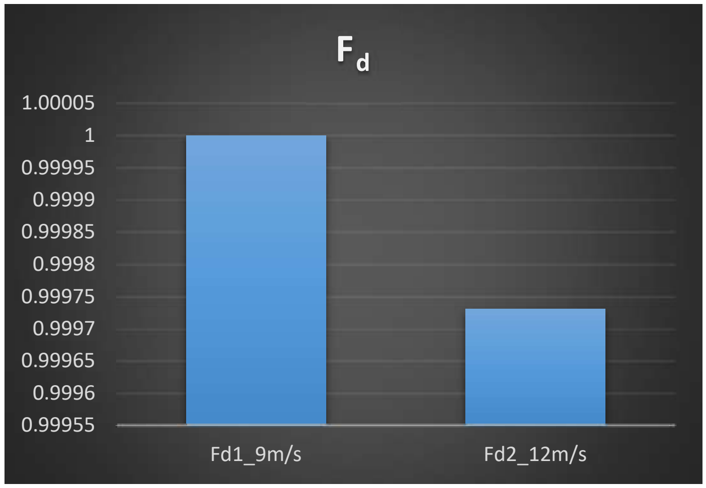


Fig showing Both F_d.

But the system is working with only 14% difference in wind i.e. from 9-12m/s and is robust throughout.

The system won't be able to withstand critical situations like storm, when the difference in wind is more than 14%.

So the future work will be to make the system be robust to any change in wind.

References:

[1] I. Guenoune, F. Plestan, A. Chermitti, and C. Evangelista, « Modeling and robust control of a twin wind turbines structure », Control Engineering Practice, vol.69, pp.23-35, 2017.

[2] F. Plestan, C. Evangelista, P. Puleston, and I. Guenoune, "Control of a wind turbine system without wind velocity information", submitted to International Workshop on Variabe Structure Systems, Graz, Austria, 2018.