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The Effect of the Presence of a Series Compensator in the Circuit on Dynamic Behavior of Two-Way Power Generators of Wind Turbines

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Abstract

One of the many types of wind turbines that are widely used in the world, Wind turbines are powered by induction generators. Due to the increasing use of this generator in wind farms and power grids as well as the increasing use of PACIS devices and compensators in the transmission lines, a careful study of behavior and their dynamic modeling is felt more and more. To this end, a small wind turbine signal model with a dual-induced induction generator is first introduced it is introduced at different wind speeds. Then using the series compensator capacitor, dynamic behavior of double induction generator in the presence of this compensator at various wind speeds, the analysis and power stability of the transmission line are investigated.

Keywords: Wind turbine, Double power supply generator, reactive power, Thyristor , TCS.

1- Introduction

Given the increasing human need for energy on the one hand and the reduction of traditional resources on the other, the need to find new sources of energy is clearly felt. Replacing fossil fuels with new energies is a long-term solution that has been of interest to advanced world countries. One of the most important is wind energy [1,9].Wind energy is cheap, abundant, clean and easily convertible to electrical energy [10] .The major problem in exploiting, predicting, not being, or hardly predictable.

There are also momentary variations of wind speed, which causes fluctuations in wind turbine output needs to be studied [9]. In this paper, we first introduce two-way feeding induction generators [4,5] and in the next step we will examine the situation that the series compensator capacitor[8] is in orbit we examine and analyze the impact on the stability of the power system[3,6,9], and ultimately through the similarities we confirm its accuracy [12].

2- Variable Speed Wind Turbines with Generator

Double-induced induction turbines use an induction generator with a double-feed winding rotor and control the speed of the generator by changing the injection voltage to the rotor. In fig.1, the schematic design of this type of turbine is shown. Rotor Feeding This Generator it connects to a power grid via an electronics transducer and this converter operates the active and reactive power control of the output of the generator separately [7].

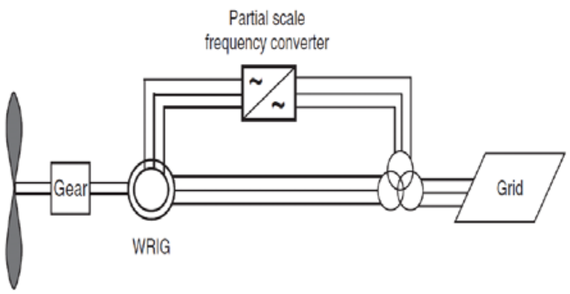

Fig.1. Variable speed wind turbine with induction generator double

Rotor-coupled converter control is performed using the principles of vector control and by controlling the inverse and direct components of the generator current (components of the device) the active and reactive power of the generator is controlled individually. The reference reactive power level is also determined based on the improvement of the turbine power factor the speed variations in these generators are usually about 40% -30% + synchronous speed the advantages of wind turbines with double induction generators include:

- The cost of the converter in these turbines is less than the turbines connected through the converter to the network. The reason for this is that the converter capacity in these turbines when the velocity changes are about 30%Usually about 30% of the generator power.
- The size of the filters in these turbines is smaller and the amount of harmonics produced in these turbines is less.
- The power factor control in these turbines is done at a lower cost. The induction generator acts like a synchronous generator in this way.
- Active and reactive power is controlled individually

3- Capacitor Series Compensator

Due to the fact that the transmission lines [11] in power networks have Safefic power networks, one of the problems of reactive power consumption in transmission lines. The transfer line is assumed to be in the form of fig.2.

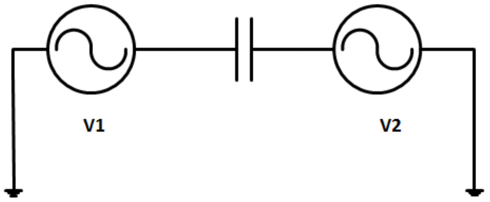

Fig.2. Transmission line with the presence of the inductor

Considering that, reactive power can increases the level of current to energy in the power grids. In order to reduce the transmission current in the transmission line, the capacitor is used in series with the transmission network. The transmission line with the presence of the capacitor of the power equation is obtained in the presence of the capacitor as follows:

$$Q = \frac{V_1.V_2.\sin(\theta_1 - \theta_2)}{-X_c} \qquad (1)$$

Transition exists; the power equation will be as follows.

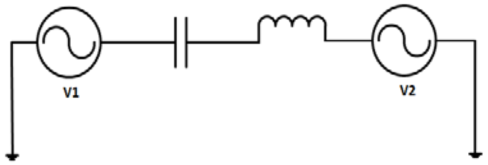

Fig.3. Transmission line with inductor and capacitor

$$Q=\frac{V_1.V_2.\sin(\theta_1-\theta_2)}{\left(X_1-X_c\right)} \tag{2}$$

As it is seen, the presence of the capacitor reduces the absorption of reactive power. By decreasing absorption, the loss of power in the transmission line decreases. Presence of capacitors in transmission lines it shortens the transmission lines by hypothetical. In other words, the presence of the capacitor of the compensator series it causes consumers to be closely related to the sources of electrical energy. But the presence of the capacitor and the inductor together cause the phenomenon to escalate, in the next chapter, the presence of a series compensator capacitor in power networks is fully explained.

4- Connect the DFIG to the Network with the Presence of the Capacitor Series Compensator

If used in the transmission line of the series compensator capacitor, the shape of the sample network will be as follows:

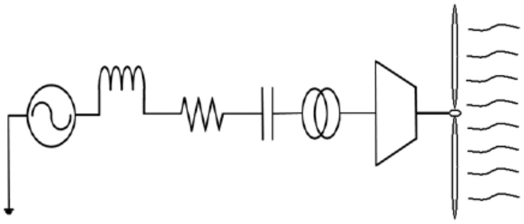

Fig.4. Capacitor Series Compensator

Infinitely connecting shin through the transmission line and with the presence of the Compensator Capacitor Series.

The stator voltage equations will also be in the presence of a series compensator capacitor as follows:

$$V_{ds-1}=R_t\left(I_{dg}+I_{ds}\right)-\frac{\left(I_{qg}+I_{qs}\right)}{\left(X_t-X_{ct}\right)^{-1}} \tag{3}$$

$$V_{qs-0}=R_t\left(I_{qg}+I_{qs}\right)-\frac{\left(I_{dg}+I_{ds}\right)}{\left(X_t-X_{ct}\right)^{-1}} \tag{4}$$

That : X_{ct} is the transmission line capabilizer.

That is obtained by calculating of special values and coefficients of participation. The stability of the system is investigated. First assumed the wind turbine, like the fig.5, is connected directly to the infinite Shin.

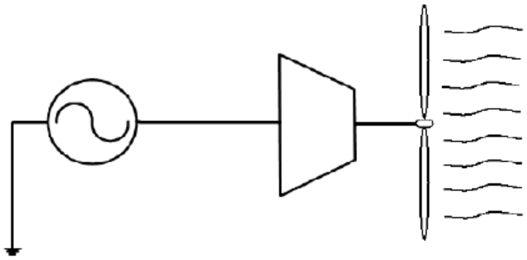

Fig.5. Direct connection to infinite X_{in}

In Table 1 lists the quantities of the studied system. All simulations by MATLAB software and using the model included in this software. DFIG is capable of operating at high speed synchronous speeds and low synchronization speeds therefore, the winding synchronous speed of the studied wind turbine is equal to 12m/s as a result, when the wind speed is lower than 12m/s, the speed of the machine goes below synchronous speed. And vice versa, when the wind speed is above 12m/s, the speed of the car will be above the synchronous speed.

Table 1. System parameters

Row	Quantity name	Size	unit	Row	Quantity name	Size	unit
1	H_t	3	S	20	Kp3	1.25	
2	H_g	0.5	S	21	Kp4	0.3	
3	D_{sh}	1.11		22	Kp5	0.002	
4	K_{sh}	1.5		23	Kp6	1	
5	B	0.01	pu	24	Kp7	1	
6	P_{nom}	1.5	MW	25	Ki1	100	
8	L_m	2.9	pu	26	Ki2	8	
9	L_s	3.071	pu	27	Ki3	300	
10	L_r	3.056	pu	28	Ki4	8	
11	R_r	0.005	pu	29	Ki5	0.05	
12	R_s	0.0076	pu	30	Ki6	100	
13	Kp1	1	pu	31	Ki7	100	
14	Kp2	0.3		32	V_{dc}	1200	V
15	R_f	0.0015	pu	33	C	0.01	F
16	Lf	0.15	pu	34	L_l	0.021	H
17	Vs	575	V	35	R_l	2.306	Ohm
18	infinity bus voltage	125	KV	36	L_T	0.125	Pu
19	Length of transmission Line	20	Km	37	R_T	0.0041668	Pu

5- The Frequency of Reactive Power Intensification and Reduction of Losses in the Transmission Lines

But the presence of the capacitor and the inductor together cause an exaggeration frequency. How to calculate the resonance frequency as below:

$$\begin{aligned} f_n &= f_e\sqrt{\tfrac{X_c}{X_L}} \\ X_L &= 2\pi f_e.L \\ X_C &= \left(2\pi f_e.C\right)^{-1} \end{aligned} \tag{5}$$

The above quantities are defined as:

f_e: Frequency of the base of the network (here the frequency of the network is 60Hz).

f_n: Resonant frequency

L: Transfer inductance

C: Compensator Capacitor Series

Given that the resonant frequency causes a resonant phenomenon in subsystems in power networks this phenomenon causes fluctuations in electromagnetic torque and system instability.

In this case, not only the use of a capacitor is not a feature of a series compensator, but will also cause system instability. When in the network a frequency lower than the main frequency of the network occurs, the phenomenon of resonance occurs below the synchronization. To be able to check the wind speed impact, here are 3 modes

- Low speed sync speed
- Sync speed
- High speed synchronization due to the large system mode matrix,

Because the number of simulations and special values does not increase, for each of the velocities a sample rate is considered. For speed, the synchronous speed is 10m/s, for high-speed sync speeds of 14m/s and synchronization speeds of 12m/s. In order to clearly investigate the effect of the Series Compensator Capacitor and not increase the number of simulations and special values, The compensation capacitor at the compensation levels is 25%, 50% and 75% respectively. The size of the capacitor of the series compensator at different compensation levels is presented in the table.

Table.2. The values of compensation series capacitor

Compensation percentage	% 25	%50	% 75
Capacitor Compensator Series	1.345mF	6.7mF	0.47mF

When the capacitor and inductor are in orbit, the frequency of resonance is obtained and it causes the frequency of the network, the frequency compensation of the network is shown in the table below.

Table.3. Expansion frequency at different compensation levels

Compensation percentage	% 25	%50	% 75
Resonant frequency	15HZ	30HZ	45HZ

Table.4 The frequency of the network in the presence of a capacitor series compensator

Table.4. Network frequency by various Compensation

Compensation percentage	% 25	%50	% 75
Network frequency in the presence of a capacitor series compensation	45HZ	30HZ	15HZ

In synchronous generators, the only effective factor in the phenomenon of resonance below the synchronous is the compensator surface; because the speed of these generators is constant. But in induction a generator, the condition varies depending on the slip these machines work in both motor and generator modes. The slip equation is defined in terms of frequency as follows. The above quantities are defined as follows :

$$S = \frac{(f_n - f_e - f_m)}{(f_n - f_e)} \quad (6)$$

f_n: resonant frequency

f_e: Network Frequency

f_m: Rotor frequency

As stated above, in the network studied frequency is equal to 60Hz, That is, at the synchronous speed, the network frequency is 60Hz. In rotary induction machines, it can continue at 3 speeds

- Under the sync speed
- Sync speed
- Above the sync speed

Here, when the wind speed is 12 m/s, the rotor continues at synchronous speed. As a result, the rotor frequency will be equal to 60 HZ. According to the above description, for the rotor speeds, the rotor frequency is shown in the following table.

Table.5. The rotor frequency by wind speed

Wind speed	12m/s	10m/s	14m/s
Rotor frequency fm	60HZ	50HZ	70HZ

Table.6 shows the rotor frequency in the presence of a series compensator capacitor according to the above tables and (6).

Table.6. The rotor frequency by different series capacitor

Wind speed	10m/s	12m/s	14m/s
25%	-0.111	-0.333	-0.555
50%	-0.666	-1	-1.3
75%	-2.333	-3	-3.667

As shown in Table.6 in cases where slippage is out of range, the system has become unstable when the wind speed is 14 and the compensation level is 50%, the system is oscillating this is due to the fact that the network frequency is about half the rotor's frequency. The values of the rotor frequency and the network frequency in the presence of the capacitor of the compensator series are presented in Tables5 and 6 respectively.

6- Simulation and Investigation of DF IG Stability in the Presence of a Capacitor Series Compensator

The values of the sample network shown in Table.1 are shown. All simulations were done by the software and using the existing model in this software.

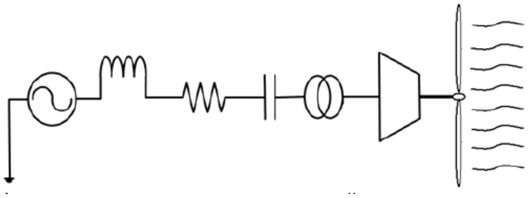

Fig.6. Wind turbine with DFIG

Table.7. The system Eigen values by capacitor series compensator at 14m/s

Number of special system values	Without the presence of a capacitor series compensator	% 25	%50	% 75
2،1	-2325.6±j661	-2332.5±j778.1	-2376.1±j894.5	-2306±j981.8
3	-414	-416.3	-413.6	-414.4
5،4	-21.7±j345.8	-10±j368.5	±j390.3	16.1±j410.2
7،6	-117.3±j66.4	-126.9±j72.5	-123.4±j78.9	-98.5±j18.8
9،8	-8.5±j85.1	-6.2±j85.4	-6.5±j85.4	-6.4±j60.1
10	-69.8	-69.9	-70	-69.8
11	-59.8	-65.4	-56	-64.91
12	-40.7	-33.6	-38.5	-29.8
14،13	-22.8±j18	-19.9±j19.7	-22.3±j19	16±j4.2
16،15	-0.20±j0.80	-0.1±j1	-0.1±j1.3	-0.4±j0.3
17	-1.4	-1.4	-1.4	-1.4

At first, the wind speed is assumed to be 14m/s. The system Eigen values for the different levels of the capacitor compensation series are given in Table.7. The following figures confirm the results and explanations given.

In all simulations it is assumed that the compensator capacitor enters the circuit and there is no capacitor before it. Also, Figs. 7 and 8 show the reactive power output curve in the presence of a series compensator capacitor at various compensating levels.

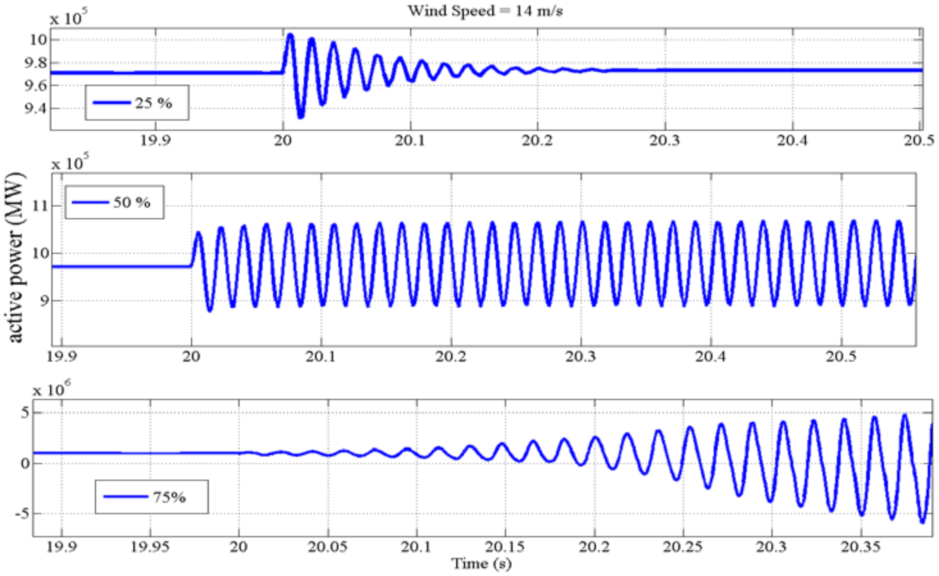

Fig.7. Active power curve at wind speed 14m/s and presence of different capacitors series compensator

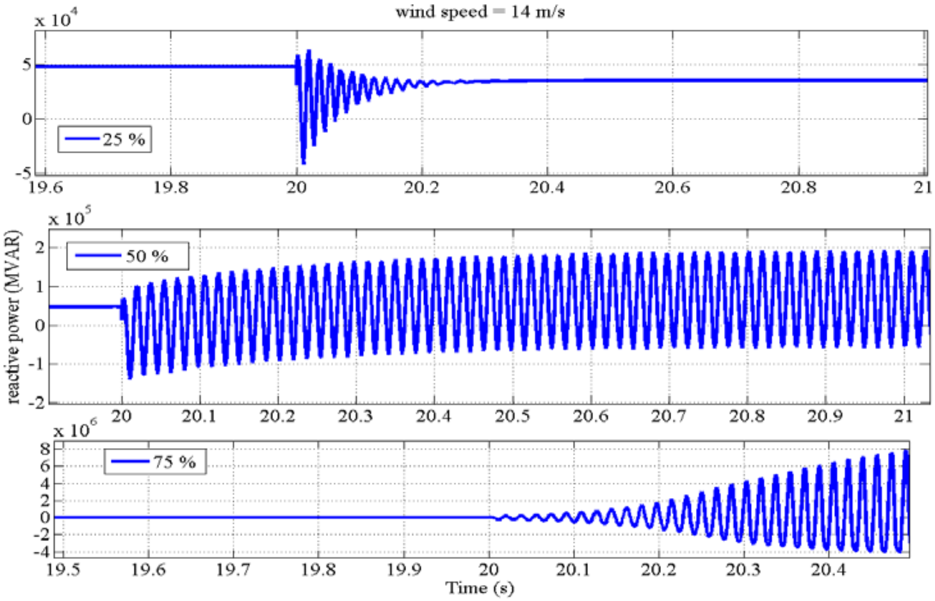

Fig.8. Reactive output curve at wind speed 14m/s with the presence of different capacitors series compensator

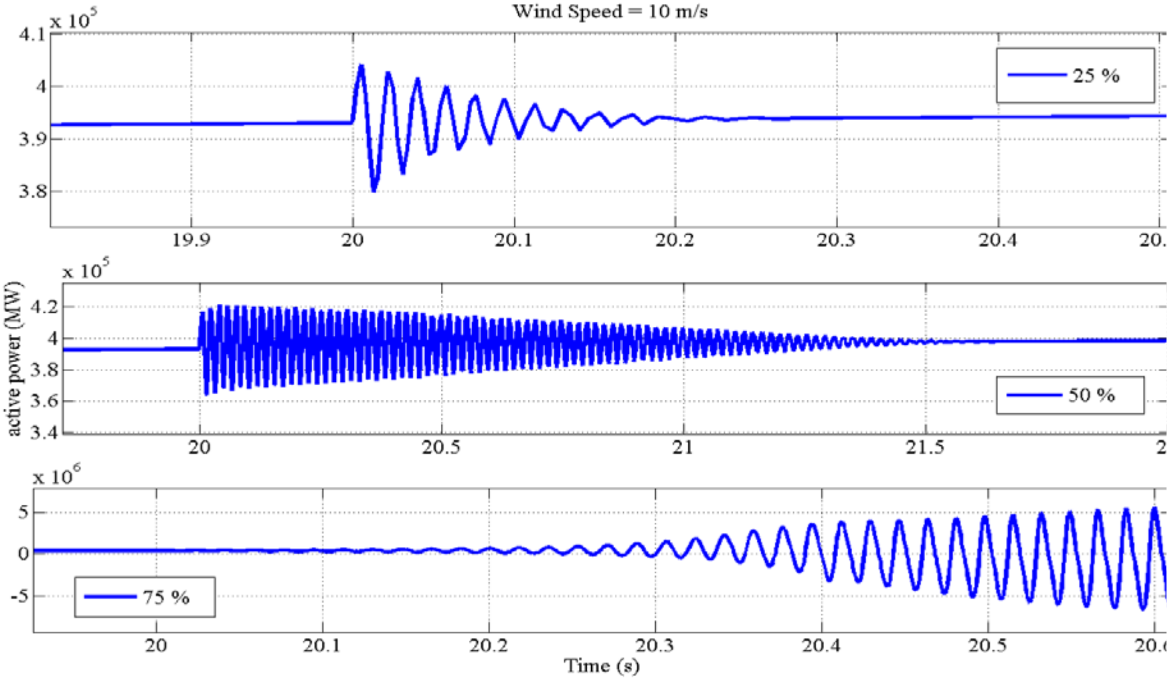

Fig.9. The active power curve at wind speed 10m/s

Fig. 9 shows the active power curve at wind speed 10m/s with the presence of different series compensation capacitors.

From the above curves it can be seen that with increasing capacitor level, the compensator system becomes unstable. This time the wind speed is considered to be 10m/s. This low speed synchronous speed, as it is seen, this time only at the level of 75% compensation of the system becomes unstable, and at other levels of the system stability is stable. The system slip also proves this in Table 6. Figs. 9 and 10 show the active and reactive power curve of the output at wind speed equal to 10m/s and different levels of the capacitor of the series compensator.

Fig. 10 shows the reactive power output curve at wind speed 10m/s with the presence of different series compensator capacitors from the above results it can be seen that when the compensation level is 75%, the system becomes unstable at all speeds. As shown in Table 6, at the compensation level, 75% of the slip is out of the range allowed in the relationship, and the system becomes unstable. By increasing the speed at the 50% compensation level, the system is stable from fluctuation. To prove this, critical points at the compensation level of 50% and wind speeds are shown in Fig. 11.

Fig. 11 shows the active power curve in the state where the compensation level is 50% and the wind speed is changing. Fig. 11 shows the active output power curve in the 50%of a series compensator capacitor and at wind speeds as can be seen, the series of compensating capacitors becomes unstable.

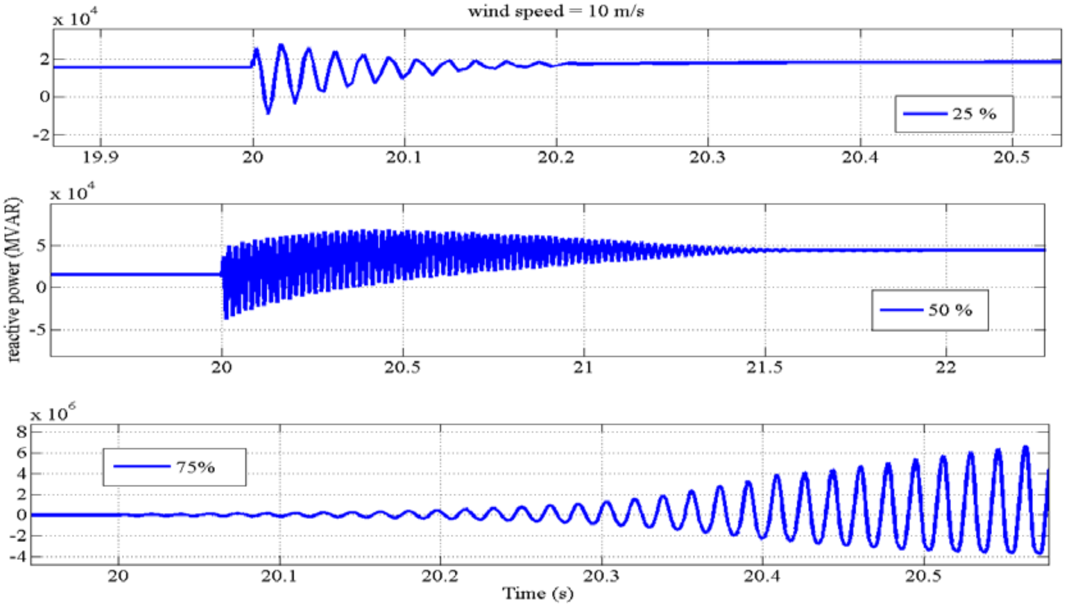

Fig.10. The reactive power output curve at wind speed 10m/s

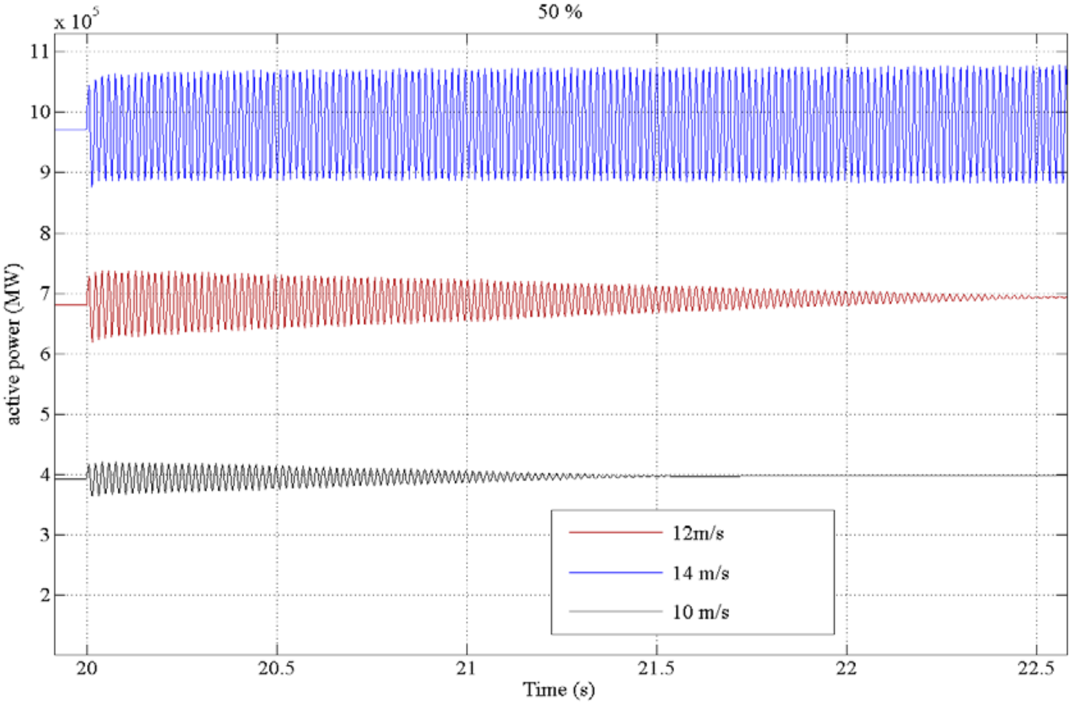

Fig.11. The active power curve in the 50% of a capacitor series compensator

Also, according to the description, the presence of capacitor series increases the level of active power and reducing reactive power. It can be seen from the above results that 50% and 75% compensation capacitors are not suitable for use in this system. Regarding the above results, it can be seen that two factors contribute to system stability:

- Rotor speed
- Capacitor level compensator series

It was observed here that the increase in wind speed in the 50% compensator capacitor caused the system to fluctuate. On the other hand, the goal is to increase productive power, and this happens when the wind speed is high on synchronous speed. These two issues are contradictory. Increasing wind speed causes system instability and decreases wind speed, reducing power output. According to the above results, for networks that are connected, capacitance is required to change its size with variation in wind speed.

7- Conclusion

The system became unstable when the compensator capacitor was present due to the appearance of the subsonic resonance phenomenon, with increasing compensation level. In the presence of a series compensator capacitor, increasing wind speed increased the system slip and increased system instability. The presence of a capacitor in the series compensator reduces the reactive power absorption and increases the active power level. Among the different levels of compensation, only the 25% offset level is appropriate. According to the available results, the presence of a series compensator capacitor for wind turbines with an induction generator is not suitable for double feeding.

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