Wind Power Integration on Interconnected or Isolated Upstream Facilities

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***Abstract*—In this paper electric studies considering an oil upstream facility with wind power and conventional generators are presented. Static power flows are performed. The voltage variations and reactive power requirements are analyzed. Also dynamic fault simulations, with and without the island formation are performed. The objective is to assess the impact of wind power generation to be included in a typical facility, in order to achieve a satisfactory performance. This work simulates a typical upstream facility, conformed by a 10.1 kV oil network a conventional motogenerator and different types of wind power plants. Wind turbine models and controls for electromechanical transients are used.**

Dynamic simulation, upstream pumps, power flow, wind power plant

I. INTRODUCTION

Due to a possible modification on Argentinean laws that would mandate purchase of a certain percent of renewable energy, some oil companies located in Patagonia are evaluating the installation of wind power plants in their own upstream facilities.

Motors associated to the upstream oil pumps have an irregular load. Their efficiency is usually between 65% to 75% and they also have a poor power factor.

These types of oil systems are connected to points in the network where the short circuit power is usually weak, and they are subject to different disturbances and physical phenomenon, which may cause the system to collapse. Therefore, they are disconnected from the network when these disturbances occur, and they keep working in an electric island.

The facility operator is interested in reducing the energy purchased from the system and has considered to install new generation. It may be conventional generation or a wind power plant.

Upon the inclusion of wind generation, it becomes necessary to study its feasibility to work connected to the transmission network, taking the wind variability into consideration, and the possibility for it to work on island upon failures in the public network.

II. CASE DESCRIPTION

A. Facility description

The facility is located in Patagonia and it is connected to the 132 kV system through two 12 MVA 132/10.1 kV transformers as shown on Figure 1. The total demand of the plant is about 30 MW. The short-circuit power at the main 10.1 kV buses is 180 MVA. Approximately 11 MW are crude-oil pumps. Due to the singular operating regime of the oil pumps these are modelled as motors operating at a 60% of its full load and also have a low power factor of 0.6 [1]. There are also 13 MW submerged pumps which are operated by electronic drives and in consequence are considered as static loads. Additionally, there are six conventional induction motors that sum up total of 6 MW (four 1200 kW motors and two 800 kW motors).

The facility also owns twelve motogenerators of 930 kW each that reduce the total power consumption from the network. In case of a system fault a load shedding system allows the facility to operate on island with a reduced load of 10 MW. The motogenerators are represented as a lumped generator and is marked with a dotted box in Figure 1.

B. New generation proposed

The new proposed generation may be conventional or wind power generation. There are two proposed types of wind power plants technologies. The first one (Case 1) is a wind power plant of 12 MW formed by Squirrel Cage Induction Generators (SCIG). The second alternative (Case 2) is a 12 MW wind power plant of Permanent Magnet Synchronous Generators (PMSG). This type of technology is capable of controlling voltage and has a ±6 MVAr limit.

Alternatively a case with a 12 MW conventional generator (Case 3) with the same characteristics as the existing motogenerators is also proposed.

In the three cases the possible new generation is modelled as a lumped generator and its location is marked with a dashed box in Figure 1.

In order to study its feasibility, the cases previously mentioned are simulated using the program PSS ®E v32.2. The facility is modelled considering the interconnected Argentinean power system.

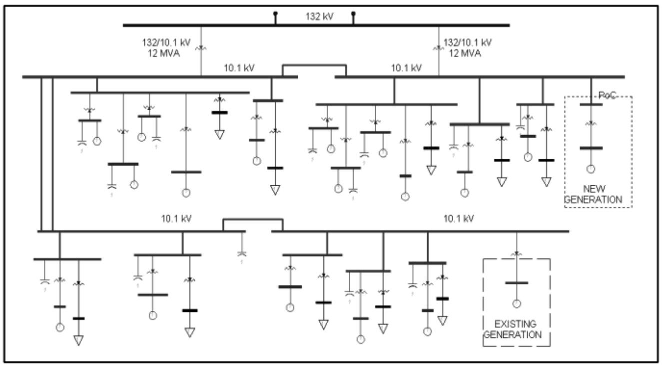

Figure 1. Facilty diagram

III. SIMULATIONS

A. Power flow

In order to assess the impact on the voltage profile in the bus bars, power flows considering the different cases are modelled. The worst case scenario in all cases is when the new generation is delivering the maximum output and a sudden disconnection occurs. If the voltages in the facility bus bars stay between a ±5% its nominal rate, it is possible to say that the new generation does not affect the normal operation.

In Case 1 (SCIG), the wind power plant cannot control voltage and works operating with a power factor of 1. In order to achieve this power factor, a switching capacitor bank is considered inside the power plant.

Cases 3 and 4 are very similar since the PMSG and the conventional generators are both capable of controlling voltage. In both cases the new generation is controlling the voltage at the point of coupling (PoC in Figure 1) in 1.05 pu.

After disconnecting the new generation, all buses remain between the admitted limits in the three cases. There is no negative impact on the facility voltage upon the inclusion of any of the technologies analyzed.

Another important issue is to determine if the response during a disturbance in the transmission network is modified due to the new generation.

B. Dynamic simulations

PSS/E library models are used for the modelling of the wind generators and the conventional motogenerators. The crude oil pumps and the induction motors are modelled with the CIMTR4 model and the values are presented in TABLE I. The crude oil parameters are based on previous modelling of these type of machinery [1].

Cases 1 and 2 are modelled as typical wind power plants and PSSE library models are used. Case 1 is modelled using the models WT1G1 and WT12T1 and values are presented in TABLE II. Case 2 is modelled using WT4G and WT4E and the values are presented in TABLE III. The values for each model are obtained from the PSSE Application manual [2].

Case 3 is modelled using GENSAL, EXAC4 and DEGOV1. The values for the parameters are based on measurements on field [3] and are presented in TABLE IV.

A first approach is to assess the performance during different types of faults. In all cases, the new generation is considered to be operating at its maximum value (12 MW).

TABLE I. MOTORS PARAMETERS

CIMTR4		
Parameter	***Crude-oil pump***	***Induction Motors***
T'	0.083	1.83
T"	0	0.0065
Inertia	0.5	1.5
X	2.29	3.52
X'	0.138	0.23
X"	0	0.1587
Xl	0.07	0.01
E1	0	0
S(E1)	0	0
E2	0	0
S(E2)	0	0
D	0.5	2
Synchronous Torque	-0.84	-0.82

TABLE II. MODEL PARAMETERS FOR CASE 1 WIND POWER PLANT

WT1G1		***WT12A1***		***WT12T1***	
Parameter	***Value***	***Parameter***	***Value***	***Parameter***	***Value***
T'	0.846	Droop	0.015	H	5.3
T"	0.00	Kp	0.1	DAMP	0
X	3.927	Tl	0.015	Htfrac	0.918
X'	0.1773	T1	0.1	Freq1	5
X"	0	T2	0.1	DSHAFT	1
Xl	0.1	Tpe	0.1		
E1	1	LimMax	0.9		
S(E1)	0.03	LimMin	0.25		
E2	1.2				
S(E2)	0.179				

TABLE III. MODEL PARAMETERS FOR CASE 2 WIND POWER PLANT

WT4G1		***WT4E1***			
Parameter	***Value***	***Parameter***	***Value***	***Parameter***	***Value***
TIQCmd	0.02	Tfv	0.15	dPMN	-0.5
TIpCmd	0.02	Kpv	18	T_POWER	0.05
VLPL1	0.4	Kiv	5	KQi	0.1
VLPL2	0.9	Kpp	0.05	VMINCL	0.9
GLVPL	1.11	Kip	0.1	VMAXCL	1.1
HVRC	1.2	Kf	0	KVi	120
CURHVRCR	2	Tf	0.08	Tv	0.05
Rip_LVPL	2	QMX	0.47	Tp	0.05
TLVPL	0.02	QMN	-0.47	ImaxTD	1.7
		IPMAX	1.1	Iphl	1.11
		TRV	0	Iqhl	1.11
		dPMX	0.5		

TABLE IV. MOTOGENERATOR PARAMETERS

GENSAL		***DEGOV1***		***EXAC4***	
Parameter	***Value***	***Parameter***	***Value***	***Parameter***	***Value***
T'do	2.56	T1(sec)	0.03	TR	0.02
T"do	0.008	T2(sec)	0.01	ViMAX	0.2
T"qo	0.006	T3(sec)	1.6	ViMIN	-0.2
Inertia	0.5	K	3.31	TC	1.4
Damping	0.2	T4(sec)	0.14	TB(sec)	100
Xd	1.6	T5(sec)	0.28	KA	300
Xq	0.97	T6(sec)	0.6	TA	0.1
X'd	0.27	TD(sec)	0.01	VRMAX	5
X"d	0.15	TMAX	1.1	VRMIN	0
Xl	0.15	TMIN	0	KC	0
S(1.0)	0.2298	Droop	0.03		
S(1.2)	1.0104	TE	0		

- Fault 1. Single phase short-circuit

A single phase short-circuit in the power line that feeds the facility with reclosing is modelled. The short-circuit stands for 100 ms and then the faulted phase opens and recloses 400 ms later.

Figure 2. presents the voltage at the 132 kV bus that feeds the facility. As it can be seen, the three cases are capable of withstand the short-circuit without any inconvenient. Case 1 (SCIG) presents a lower voltage during the 400 ms when one phase is tripped.

- Fault 2. Three phase short-circuit

A 200 ms three phase short-circuit in a near 132 kV bus is modelled. In Figure 3. the voltage at the 132 kV bus that feeds the facility is presented. Figure 4. shows the voltage in one of the 1200 kW induction motors during and after the three phase short-circuit. Figure 5. presents the existing motogenerators angle for the three cases.

After the short-circuit the voltage in Case 1 does not restore to its rated value. This is due to some motors are unable to successfully reaccelerate. As it can be seen, in Figure 4, the motor voltage remains under 0.8 pu for several seconds. This condition would probably trip the motor protection.

In Case 2 the 132 kV voltage successfully restores to the previous level due to the reactive power delivered by the wind power plant after the shortcircuit.

Case 3 does not recover after the short-circuit. The motogenerators loose synchronism after the short-circuit as it can be observed in Figure 5.

In Cases 1 and 2 the new generation does not participate in angle stability since the SCIG are induction generators and the PMSGs are decoupled from the grid by the full converters.

In Case 3, upon a severe short-circuit as it was modelled, motogenerators loose synchronism due to its low inertia and are unable to recover [4]. A fault similar as the modelled would probably trip the island formation and would allow the facility to keep operating on a reduced load disconnected from the rest of the electrical system.

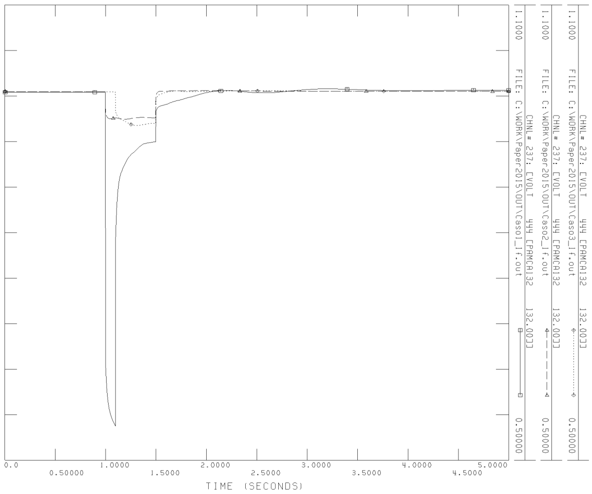

Figure 2. Fault 1. Voltage at 132 kV bus for Case 1 (full line), Case 2 (dashed) and Case 3 (dotted)

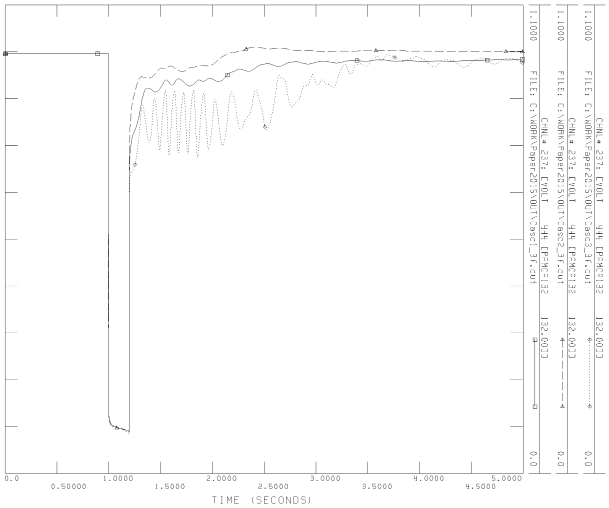

Figure 3. Fault 2. Voltage at 132 kV bus for Case 1 (full line), Case 2 (dashed) and Case 3 (dotted)

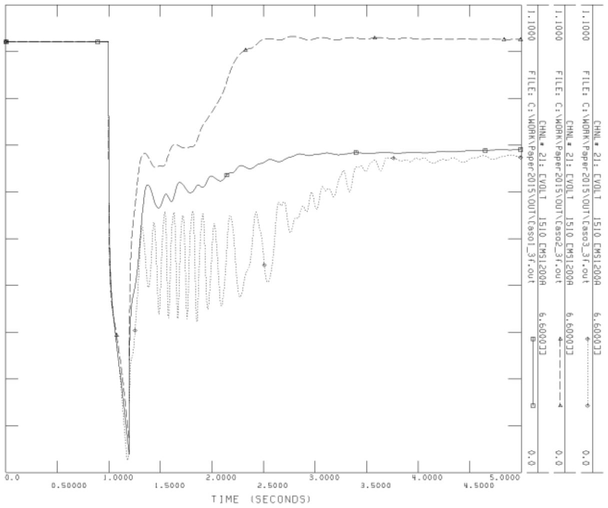

Figure 4. Fault 2. 1200 kW motor voltage for Case 1 (full line), Case 2 (dashed) and Case 3 (dotted)

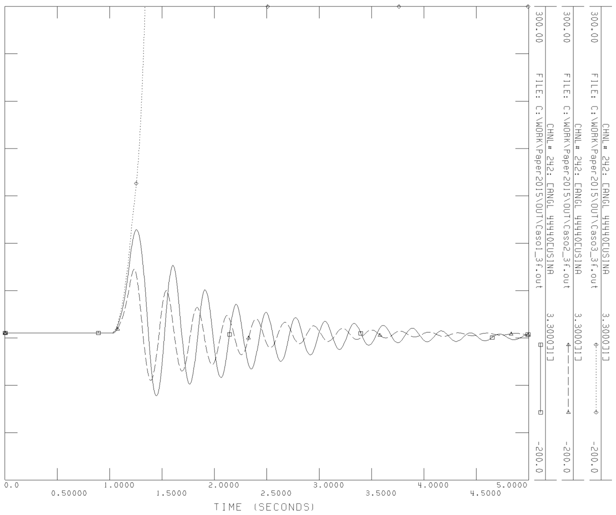

Figure 5. Fault 2. Existing generator angle for Case 1 (full line), Case 2 (dashed) and Case 3 (dotted)

- Fault 3. Three phase short-circuit partial load.

Based on the obtained results a new scenario is modelled. In this scenario the new generation is in partial load, delivering only 2 MW (in the three cases) and the same three phase short-circuit is modelled (Fault 2). Figure 6. presents the voltage at the same 132 kV bus shown in Figure 3. Figure 7 presents the voltage at one of the 1200 kW induction motors.

The voltage for Case 1 shows a slower recovery than cases 2 and 3. This is associated to the motors reactive power demand during the reacceleration as it can be seen in Figure 7. .

In Cases 2 and 3 the reactive power delivered after the short-circuit by the new generation, enables a quick voltage recovery. In this scenario, Case 3 does not loose synchronism.

The capability of the new generation to deliver reactive power is essential for an adequate response after a severe fault such as a three phase short-circuit.

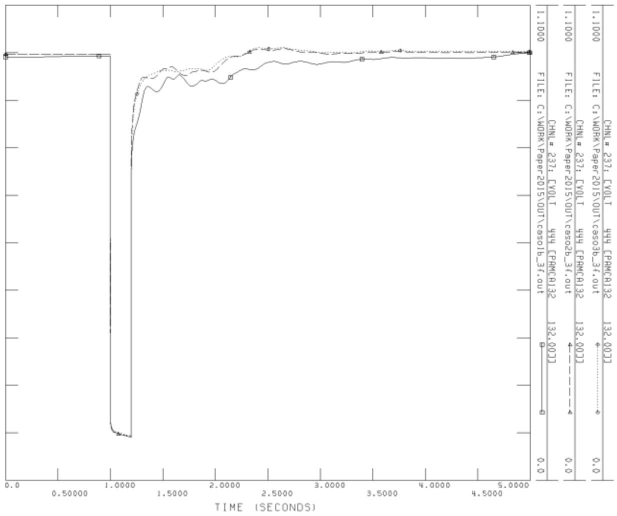

Figure 6. Fault 3.Voltage at 132 kV bus for Case 1(full line), Case 2 (dashed) and Case 3 (dotted) deñl

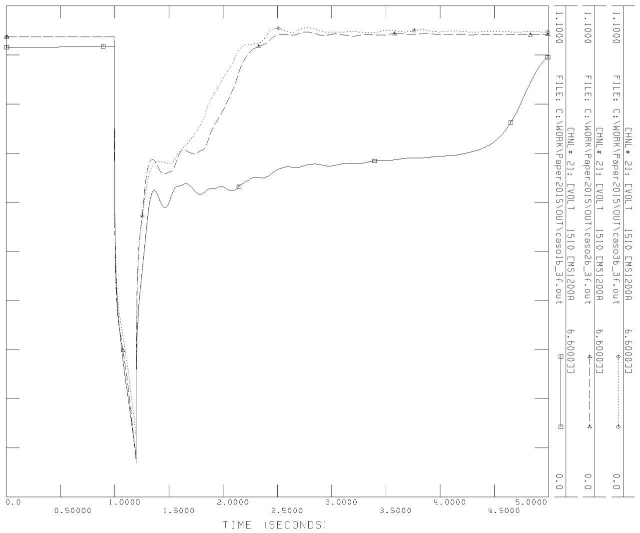

Figure 7. Fault 3. 1200 kW motor voltage for Case 1 (full line), Case 2 (dashed) and Case 3 (dotted)

C. *Island formation*

As it was mentioned before, the facility is capable of operating isolated from the grid with a reduced load. It is of interest to assess if the new generation will be able to withstand the island formation.

A single phase short-circuit with an unsuccessful reclosing in the power line that feeds the facility is modelled. The short-circuit stands for 100 ms and then the faulted phase opens and recloses 400 ms later. When the power line recloses, the fault remains and 50 ms later the island is formed. With the island formation, 7 MW of load is disconnected. The existing and the new generation are considered delivering 12 MW each. Figure 8. presents the voltages at the 10.1 kV main facility bus. The plant voltage in Case 1 (SCIG) collapses and cannot withstand the island formation. The reactive power delivered by the existing motogenerators is not enough to restore the voltage.

Cases 2 and 3 are capable to withstand the island formation. In the event of wind variation, in Case 2 (PMSG) further load shedding would be needed.

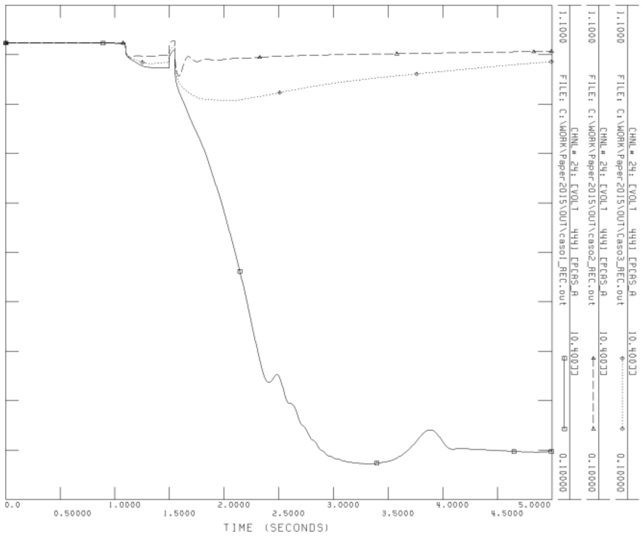

Figure 8. Island formation. Voltage at 10.1 kV bus for Case 1(full line), Case 2 (dashed) and Case 3 (dotted)

In order to assess this scenario, the same fault is modelled for Case 2 considering that the wind power plant is only generating 2 MW. Instead of 7 MW of load shedding, in this case 20 MW are disconnected.

This case is compared with the current situation of the facility. The objective is to determine if the presence of the PMSG wind power plant helps the operation on island even though is not delivering power.

Figure 9. shows the voltage at the 10.1 kV main bus for the Case 2 and the current situation (with only the existing generation). The presence of the wind power plant presents a better voltage response after the island formation. The temporary over voltage is shorter when the wind power plant is considered. Also the voltage previous the short-circuit is better.

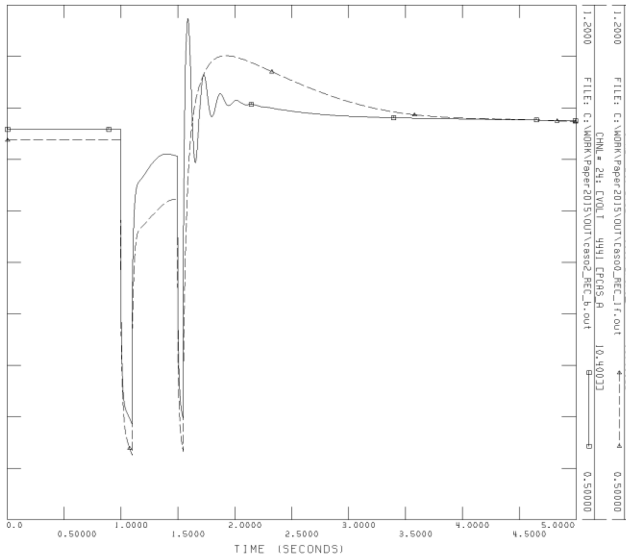

Figure 9. Island formation. Case 2 reduced wind power generation. 10.1 kV bus voltage for Case 2 (full line) and current situation (dashed)

IV. CONCLUSIONS

Different technologies of generation were considered and modelled.

The impact on the facility voltage was analyzed for different scenarios. In normal operation, the presence of new generation does not generate voltage disturbances.

Upon system disturbances such as short-circuits, the analyzed technologies respond in a varied way. The SCIG wind power plant modelled in Case 1 may worsen the current facility response since it is unable to deliver reactive power. During voltage recovery after the short-circuit, the SCIG demands reactive power and causes motors to stall. And since is unable to provide reactive power, island operation is restricted to the current situation.

The responses obtained from Case 2 simulations show that the PMSG wind power plant has certain advantage in comparison with the other cases when the facility is subjected to a severe short-circuit. The wind power plant is capable of delivering reactive power to the facility and since it is fully decoupled from the grid, it does not loose synchronism. In island operation, the amount of load remaining in operation will rely on the wind. However, even when the wind power plant is not delivering power, its presence helps the voltage recovery.

The results obtained from Case 3 simulations show that contrary to what it was expected, the conventional generation may impact negatively on the facility operation when subjected to disturbances. The motogenerators low inertia may affect the dynamic response and cause both generators to trip for loose of synchronism. Island operation with the motogenerators is proven to work since is the current operating situation.

V. REFERENCES

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