Intentional Islanding in Power Systems with Dispersed Generation

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Absctract— **The expansion and diversification of the Uruguayan energetic infrastructure, with significant penetration of renewable sources is leading to structural changes in the power system, in both transmission and distribution subsystems. These changes impact in the operation criteria and also in the power system protection.**

The paper studies one of the phenomena that arises in the new scenarios of the power system: the possibility of islanding operation of systems including these new geographically dispersed generators. This new scenario poses challenges and also opportunities, since that the controlled islanding may constitute a valuable protective strategy in some cases.

The case study includes both wind and biomass generators that in certain cases are shown to be able to operate in island following major disturbances.

Index Terms-- Wind generators, dispersed generation, distributed generation, intentional islanding, protections.

I. Nomenclature

GD Dispersed generation or distributed generation

DAC Automatic load shedding

DAG Automatic generator disconnection

II. Introduction

The traditional layout of the Uruguayan power system used to be characterized by two big generation areas, backed up by international AC interconnection. One generation area is located in the northwest and centre of the country which is responsible for the hydro generation. The other is located in the south and concentrates the oil-based generators and the biggest load. Now, Uruguay is dealing with challenges in its energetic infrastructure, as a consequence of the growth of the demand, the fuel prices, and a worsening of the hydro scenario. The answer to this panorama is the ongoing plans of energetic expansion and diversification that specify, between others, the appearance of multiple, geographically distributed, private generators, mostly wind-based generation and biomass. These distributed generators are about 50MW-size and are being connected at the transmission level; being the wind-based generation the one that has most investment in Uruguay. The high penetration of the wind power, its variable output characteristic and its essentially autonomous dispatch increments the concern about stability issues.

Currently, the islanding operation of these generators is not an allowable practice, due to the risk for people and equipment. The code IEEE 1547 [4] recommends special equipment to detect the islanding operation and suggests a limit of 2 second to the islanding operation. However the controlled islanding seems to be a valuable alternative protection strategy since it can reduce the impact of severe disturbances and allow a faster restoration, see references [1,3,9,10]. These last two references describe studies on the Uruguayan electrical power system based on distance protective relays or synchrophasors.

In the case under study, the utility requires specific protective functions in order to avoid islanding operation for the wind and biomass generators. However, it also has the right to request the islanding operation under special circumstances [5].

III. The Islandig Problem

The incorporation of distributed generation can improve the confiability and reliability of the power system, if the new generation are able to support the electrical supply in island situation. Islanding is defined as “A condition in which a part of the power system that have both load and generation resources remains energized while isolated of the rest of the power system”. In order to avoid damage in the equipment, the island condition should be controlled and well implemented [2]. Also, the generation resources should be equipped with excitation control and speed governors with capacity of local voltage and frequency control.

The preceding studies on islanding conditions in the Uruguayan power system, references [9,10], are based on conventional synchronous generation and no wind generation.

A corrective control strategy that splits the power system into controlled self-sustaining islands requires the following studies under various forecast load conditions and contingency scenarios:

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- Planning Studies: in order to verify that the voltage and frequency magnitudes, in every island, are between the boundaries allowed by the regulation. As well, these studies verify the capability of the lines and transformer during the island condition, to satisfy the demand without restriction.
- Stability Studies: in order to study the interaction between the generators in the island, and between the generators and the load, verifying the stability in each island.
- Power Flow and Short-circuits Studies: in order to secure that the protections system located in the lines and generators in the island, will detect properly the faults during the island condition. These studies may conclude that new protection systems should be installed.

The basis for forming the islands is to minimize the generation-load imbalance in each island thereby facilitating the restoration process. Then, by exploring a carefully designed load shedding scheme based on underfrequency protection [6], we limit the extent of the disruption, and be able to restore the system rapidly.

Operational boundaries [7]: with the intention of evaluate if the islanding condition is possible, some boundaries are taking account. These boundaries are established in the local regulation and are the following:

- Off nominal voltage operation:
  - between 0.93 and 1.07 pu of nominal voltage for steady state conditions.
  - between 0.9 – 1.1 pu of nominal voltage after simple contingency scenario, for less than 60s.
  - between 0.85 - 1 2 pu of nominal voltage after any contingency scenario, for less than 60s.
- Off nominal frequency operation:
  - between -0.2 and +0.2 Hz for steady state conditions.
  - between -2.5 and +3 Hz after any contingency scenario for less than 3s..

IV. Software and Models

This investigation was performed with the software DSATools [2] that includes the analysis of transient stability and power flow.

The scenarios under study and their operational parameters had to be defined as part of the inputs to begin the studies. This was done by migrating to DSAT the original PSS/E model of the Uruguayan system including detailed excitation control models and the wind-based generators [11].

A. Wind plant – wind machine

In the system under study there are located two wind plants. The first plant's power rate is 42MW and the second plant is formed by three groups of wind machines, one of 50MW and the other groups of 7.5MW each.

The model of the wind machine is applied in the system is suitable for transient studies. It is based in the model of Vestas' V80, a doubly fed induction generator (DFIG), 2MW.

The machine is a conventional wound rotor induction machine, which is provided with a solid-state voltage converter AC excitation system. The AC excitation system is supplied through an AC-DC-AC converter.

General conditions applied to wind generation:

- control the voltage constant in the connection point.
- power factor = 1

When the wind generator is connected in such point with high short-circuit currents, the reactive power that come from the wind generator is zero. In the connections points with low level of short circuit currents, the wind generator can help regulating the voltage, reducing the active power delivered to the power system. [8]

B. Synchronous generator:

In the power system under study there is located a biomass-based thermal generator with 10MVA of power rate. It has been assumed typical model for the machine, exciter system and the governor.

For the dynamic modelling of the synchronous generators, it has been applied the model's library developed in previous works.

- Generator's model: This generator has been represented by the GENROU's model, which is a good model for a generic round rotor.
- Governor's model: The IEEEG1 governor's model is the model recommended for steam turbines.
- Exciter system: After a very exhaustive study of exciter system models existing in the library, the IEEET2 model has been employed.

C. Load model

The load model uses in the present study is the result of a study made by CESI:

- P = 70% constant impedance + 30% constant power
- Q = 100% constant impedance

V. Installations Studied

The islanding operation of the distributed generators is common issue among utilities, which is still under study [3]. In case of disturbance and programmed outgoing, this kind of operation is reliable and provides continuity.

The power system under study:

The system under study has both wind and biomass electrical units in service, is a future scenario with the project that are planning to connect in these part of the power system. Fig. 1 depicts a schematic diagram of the network, showing the located the part of the system of interest, it is located near Bifurcación (BIF) 150 kV substation in the south-east of the country. This system is connected to the BIF substation by two lines that link to the NVA substation.

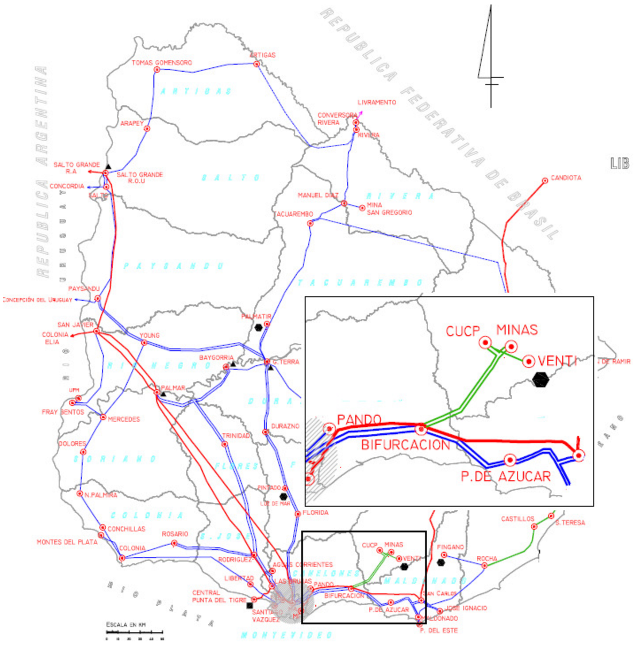

Fig. 1: System under study is located near Bifurcación, in the south-east of the country

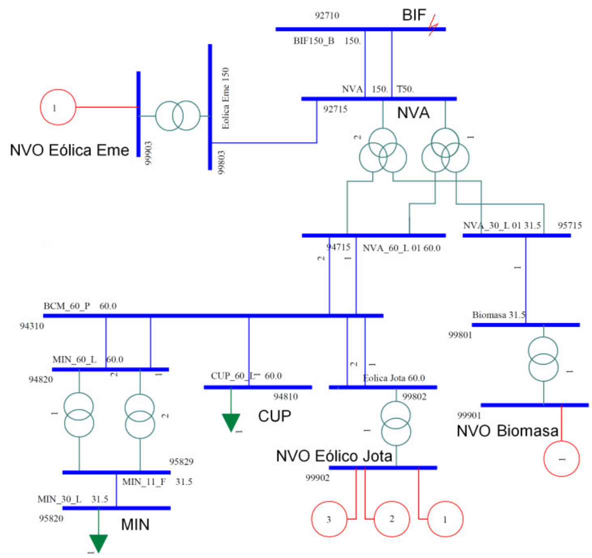

Fig. 2: Single line diagram of the investigated part of the Uruguayan transmission power system.

Fig. 2 presents the single line diagram of the investigated part of the Uruguayan transmission power system. The diagram highlights the 150 kV lines that are been opened to form the island.

Table I presents some information about the wind and biomass machines, located in the system under study. In this system there are two big consumers' centers, shown in Table II.

TABLE I
WIND AND BIOMASS MACHINES

ID	Nombre		kV	Base MVA
99901	NVO Biomasa 1 Gen.	In/Out	11	10
99903	NVO Eolica Eme 1 Gen.	In/Out	11	42
99902	NVO Eolica Jota 1 Gen.	In/Out	11	50
99902	NVO Eolica Jota 2 Gen.	In/Out	11	7,5
99902	NVO Eolica Jota 3 Gen.	In/Out	11	7,5

. TABLE II
CONSUMERS' CENTERS

ID	Nombre				MW	MVAR
94810	CUP_60_L 60.0	1	Load Bus	In	7	2.3
95820	MIN_30_L	1	Load Bus	In	21.5	7.1

For controlling the voltage and the frequency, some controls have been successfully implemented, reactive power – voltage (Q-V) control and active power – frequency (P – f) control [1]. In the case under study, the island is formed by wind generators and with also a biomass generator.

VI. Simulations

Two different scenarios have been considered, in the first there is a balance between the generation and the load in the power system under study and the second the load is larger than the generation. Two different system separations have been simulated, suddenly line opening and the opening of the lines as a consequence of a disturbance. In all the scenarios included in the present research, the wind plant Eólica Eme is always out of service.

The results of the simulation with and without load shedding are compared.

In Table III is presented the different scenarios under study with the pre-contingency conditions and the disturbance analyzed which lead to the islanding condition.

TABLE III
DIFFERENT SCENARIOS UNDER STUDY

Case	Previous Exchange	Generators in service	Disturbance
1	Small gen excess	Biomasa	Manual Trip
2	Small gen excess	Eolica Jota 2	Manual Trip
3	Small load excess	Biomasa+Eolica Jota 2	Manual Trip
4	Small load excess	Biomasa+Eolica Jota 2	3P SC + Protection trip
5	Large load excess	Biomasa+Eolica Jota 2	3P SC + Protection trip

A. *Case #1*

Previous to the island to arise, the system under study is transferring almost no power to the rest of the power system and only the biomass generator is in service.

The disturbance to be analyzed is the following:

1. at t=5s the BIF-NVA 1 line is open
2. at t=5.1s the BIF-NVA 2 line is open.

Pre-contingency conditions:

Biomass generator NVO 6.5MW, -2MVAr

Wind plants Jota	Out of service
Load at the island	7MW, 2.3 MVAr
Power transference from the rest of the system	0.6MW, -2MVAr

The impacts of the islanding on voltages, reactive power, frequency and active power are shown in Fig. 4. Fig. 5, Fig. 6, Fig 7 and Fig- 8, respectively.

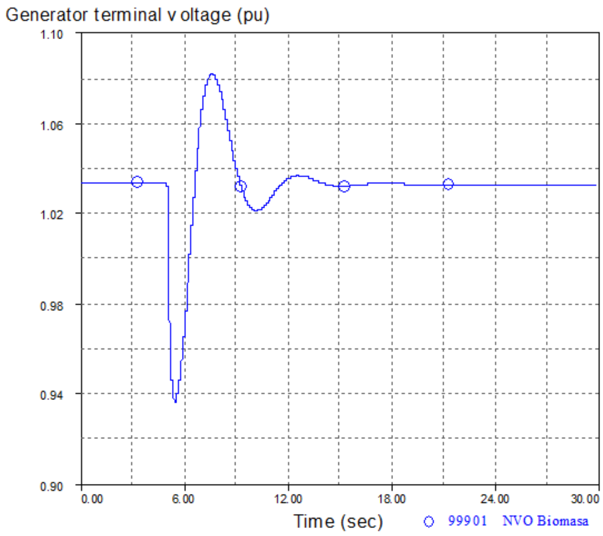

Fig. 3. Case #1 Generator terminal voltage

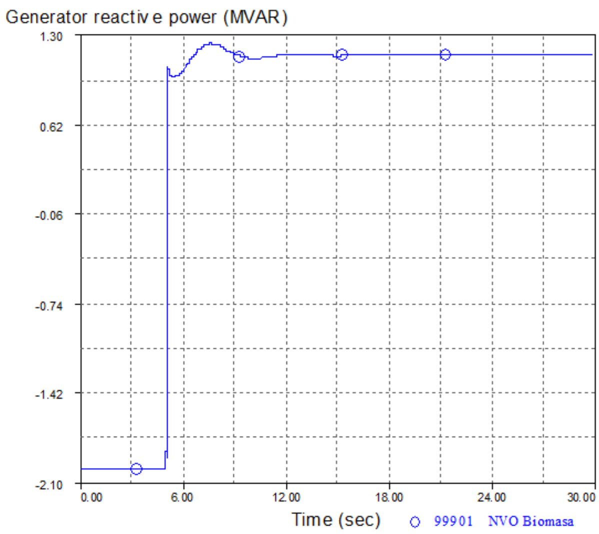

Fig.4. Case #1 Generator reactive power.

In the scenario study in Case #1, the biomass generator is able to supply the power in order to control the voltage and frequency between the accepted boundaries, during the island condition.

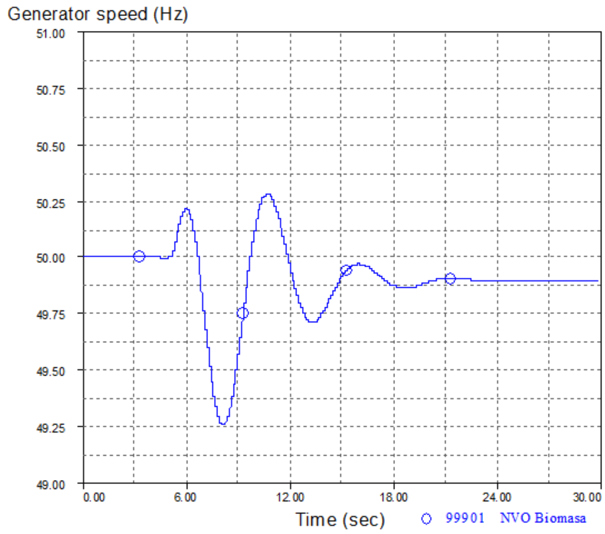

Fig. 5. Case #1 Generator speed

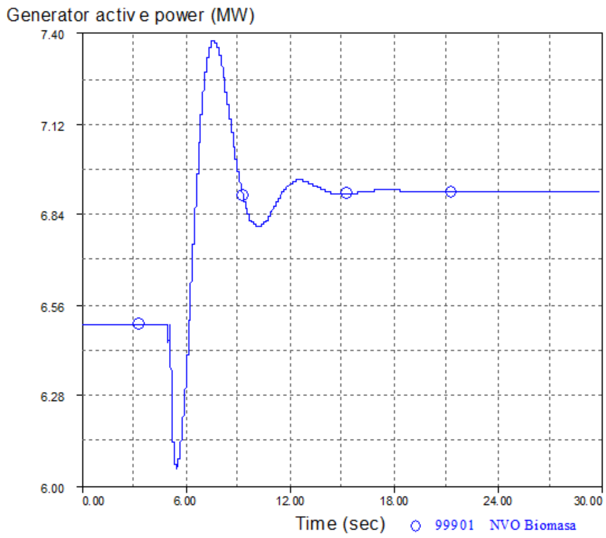

Fig. 6. Case #1 Generator active power.

B. Case #2

In order to study the behavior of the wind generator during the island condition, it was simulated the same contingency that in Case #1. In this case, the biomass generator was out of service and only one wind plant was in service, wind generator Eólica Jota. The simulation was aborted as soon as the island is formed. These results were expected due to there were no speed governor in service in the island and the wind generator was forced to optimize the active power output.

C. Case #3

Previous to the island to arise, the system under study is transferring almost no power to the rest of the power system and the biomass generator and one wind plant are in service.

The disturbance to be analyzed is the following:

1. at t=5s the BIF-NVA 1 line is open
2. at t=5.1s the BIF-NVA 2 line is open.

Pre-contingency conditions:

Biomass generator NVO	6.5MW, -2MVAr
Wind plants Jota	6MW, -1MVAr
Load at the island	13MW, 2MVAr
Power transference from the rest of the system	-0.8MW, .-0.8MVAr

The impacts of the islanding on voltages, reactive power, frequency and active power are shown in Fig. 8. Fig. 9, Fig. 10 and Fig. 11, respectively

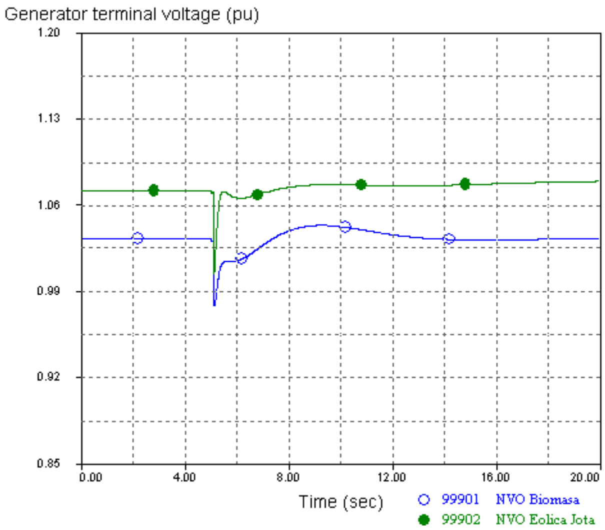

Fig. 8. Case #3 Generator terminal voltage

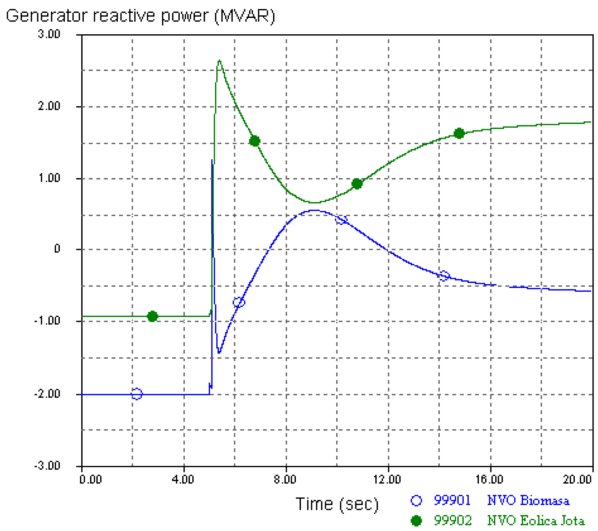

Fig. 9. Case #3 Generator reactive power.

In the scenario study in Case #2, the both generators, biomass and wind machine, supply the reactive power in order to control the voltage between the accepted boundaries, during the island condition. Only the biomass generator supplies the active power.

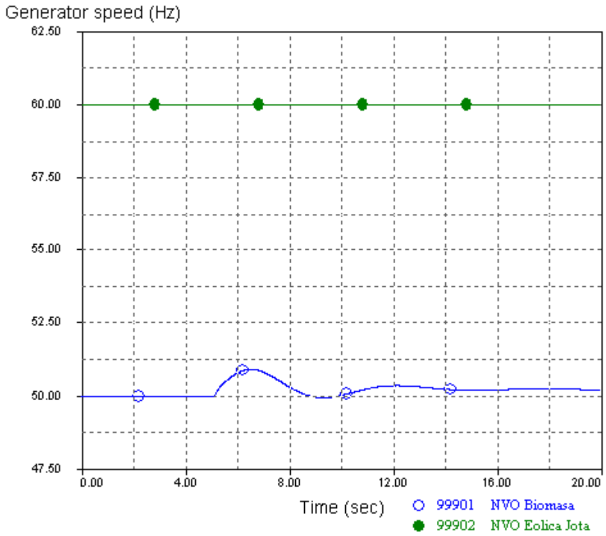

Fig. 10. Case #3 Generator speed

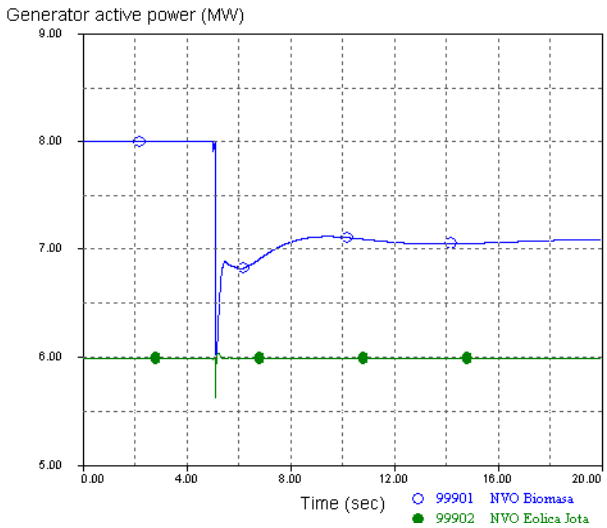

Fig. 11. Case #3 Generator active power.

D. Case #4

Previous to the island to arise, the system under study is transferring almost no power to the rest of the power system and the biomass generator and one wind plant are in service.

The disturbance to be analyzed is the following:

1. A 3-phase fault at t=4.8s, on the 150kV BIF busbar.
2. The clearance times used were:
   a. t=200ms (10 cycles) for line BIF-NVA1
   b. t=300ms (15 cycles) for line BIF-NVA2
3. The fault is removed with the complete outages of the both lines.

Pre-contingency conditions:

Biomass generator NVO	6.5MW, -2MVAr
Wind plants Jota	6MW, -1MVAr
Load at the island	13MW, 2MVAr
Power transference from the rest of the system	0.8MW, -0.8MVAr

The impacts of the islanding on voltages, reactive power, frequency and active power are shown in Fig. 12. Fig. 13, Fig.

14 and Fig. 15, respectively

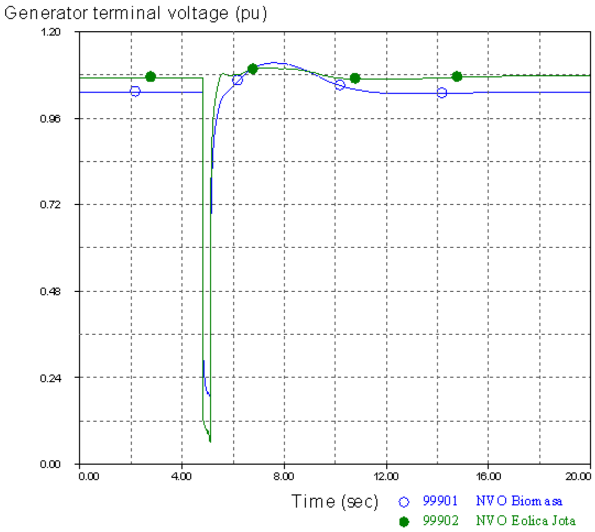

Fig. 12. Case #4 Generator terminal voltage

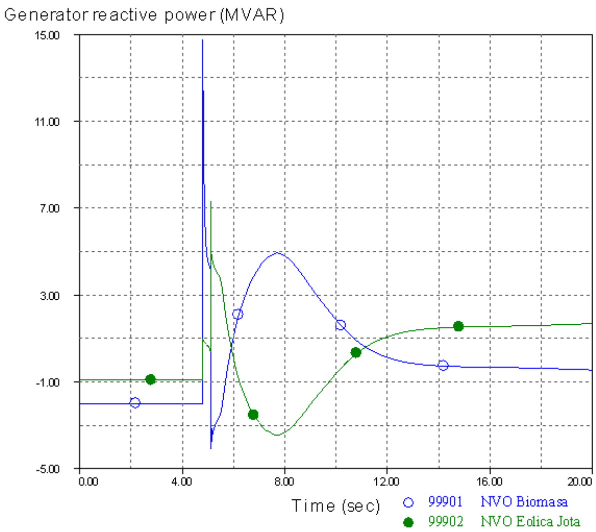

Fig. 13. Case #4 Generator reactive power.

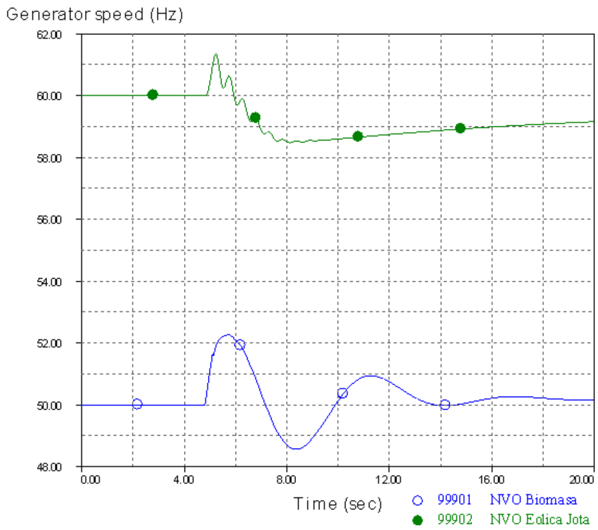

Fig. 14. Case #4 Generator speed

In this case the island is formed even after a large disturbance, but the frequency change is larger than the case in Case #1, exceeding the 52Hz.

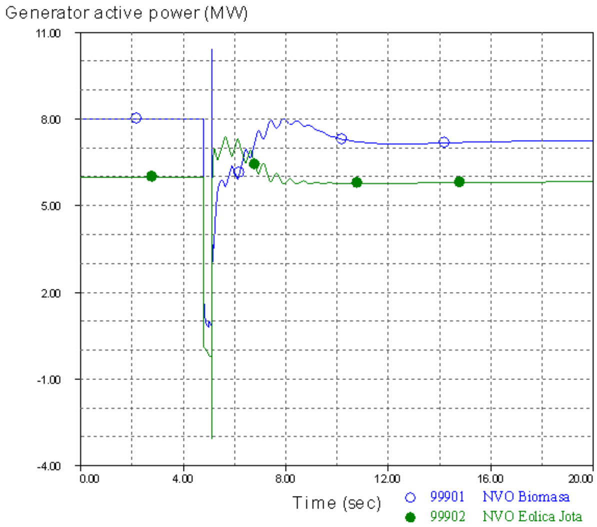

Fig. 15. Case #4 Generator active power.

E. Case #5

Previous to the island to arise, the system under study is transferring large amount of power to the rest of the power system and the biomass generator and one wind plant are in service. Since the island is not balance in load and generation, so a load shedding scheme is needed to reach the load-generation balance.

The disturbance to be analyzed is the following:

1. A 3-phase fault at t=4.8s, on the 150kV BIF busbar.
2. The clearance times used were:
   a. t=200ms (10 cycles) for line BIF-NVA1
   b. t=300ms (15 cycles) for line BIF-NVA2
3. The fault is removed with the complete outages of the both lines.
4. At t=5.4s load shed 17MW, 6.6MVar.

Pre-contingency conditions:

Biomass generator NVO	6.1MW, -2.8MVAr
Wind plants Jota	6MW, 2.9MVAr
Load at the island	27.6MW, 9.3MVAr
Power transference from the rest of the system	16.4MW, -6.6MVAr

The impacts of the islanding on voltages and frequency are shown in Fig.16 and Fig.17, respectively. In these figures are shown both cases, the one without load shedding scheme and the one with the load shedding scheme in service.

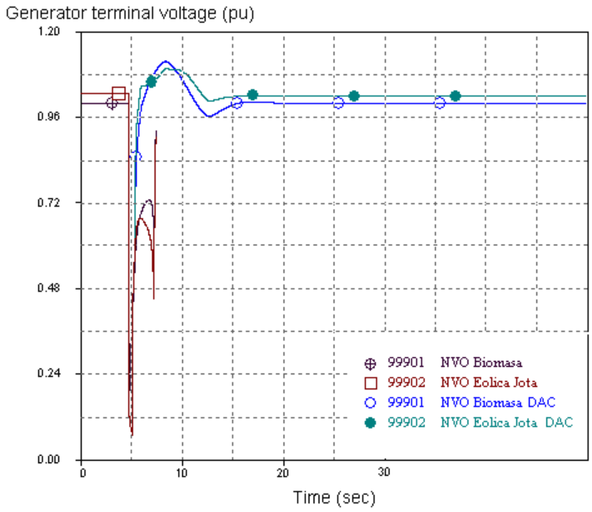

Fig. 16. Case #5 Generator terminal voltage

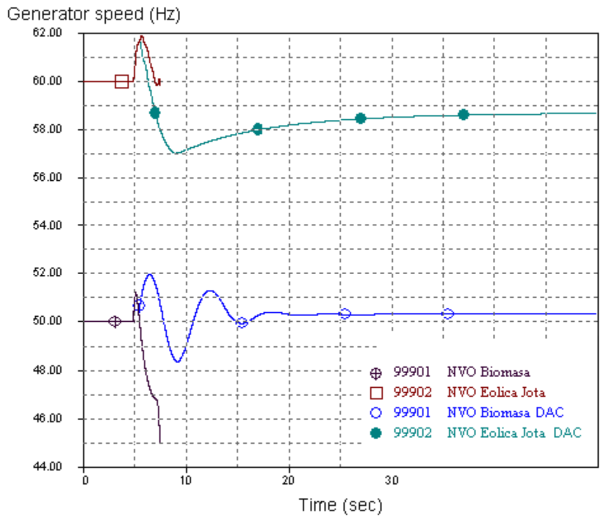

Fig. 17. Case #5 Generator speed

VII. Simulations Results

The contingencies and scenarios under study are critical, with just the biomass or with both, biomass and wind plants, in service, only a significant load shedding is able to prevent a widespread blackout, unless the power transference, among the rest of the system and the system under study, is near zero. In this condition, both generators supply reactive power in order to control the voltage between the accepted boundaries.

On the other hand, if only the wind plants are in service, the island can not be formed with the actual wind generator's control in service, even if there is a balance load-generation.

When the balance load-generation exceeds the biomass regulation capacity or the load shedding is not sufficient, the island is not stable.

The transient performance in any case was evaluated by the largest variation in the frequency and voltages magnitude.

VIII. Conclusions

The paper investigates the following technical points:

- Islanding operation including wind-based and biomass generators.
- Islanding operation under the grid operation margins.
- Behavior of the system when disturbances occur.

The investigation is based through transient stability studies covering many possible operating conditions.

Early investigations have shown that it is possible the islanding operation, including wind and biomass generators. To turn this strategy viable, load shedding is necessary. The amount of load shed will be used as a figure of merit to compare different control strategies to implement by the generators.

The present investigation has shown that an island condition can be performed when there are in service biomass generation and wind plants. Protection's system performance during the island condition and reconnection studies are now been carried out.

In order to reduce the amount of load shed during the island condition, there are some future researches to perform with the wind plants' control.

In those cases that the generation exceeds the load, DAG scheme should be studied and implemented, for that reason the actual wind plant model should be changed.

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