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Grid Islanding for Secure Operation of Power System

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Abstract- *In order to increase the reliability of the power system intentional islanding strategy has been considered by utilities. Millions of customers are affected each year due to blackouts. Splitting a transmission system into smaller islands could significantly reduce the effect of these blackouts. This paper proposes an intentional islanding method to enhance the voltage stability. In islanding operation relying on the hydraulic turbine governor (HTG) which specifically performs the speed and active power control of the islanded generators is the main achievement. This paper shows the behavior of a distribution network consisting of hydro generators.*

Keywords- *Islanding, Blackout, stability, Hydraulic Turbine Governor (HTG)*

I. INTRODUCTION

When considering a high penetration of interconnected grid, the decision to cease operation of generators when islanding occurs is not appropriate. The utility shall fully utilize the available generation to continue supplying power to the load in the islanded system. For this purpose a proper control of an islanding operation is required. Without proper control, it is not possible to implement islanding. And also it could create risks and hazards to the island and grid. So, it is mandatory to have a smart distribution system so called 'smart grid' consisting of monitoring, advanced control and communications capabilities that can facilitate automation control for a stable and seamless islanding operation.[1]

For the planned/intentional islanding operation to be feasible a great attention must be given towards several technical issues of islanding. Power quality, out of phase synchronism and protection system are the main issues. An appropriate controller need to be developed for the generator to operate in two operation modes i.e. grid connected and islanding[2]. Most significance point is to ensure that the frequency and the voltage of the island is dynamically stable and within their acceptable limit.

In case of a fault or transient disturbance the frequency response of islanded system could be more severe. The total system inertia increases with the size of the islanded system. If the system inertia is small there will be a quick frequency drop. The system has limited spinning reserve to cover the generation that has been lost from other part of grid. These limitations have justified the requirement of proper control in intentional islanding strategy.

In this paper an intentional islanding strategy has been discussed that includes a generator controller for islanded operation. The system works for two cases i.e. grid connected mode and islanded mode. The study is simulated using the MATLAB/SIMULINK simulation tool. The strategy utilizes load flow and machine initialization tool of powergui block which permits commencing of simulation in steady state.

II. ISLANDING SCENARIO

When the distribution network disconnects from the grid there will be a huge impact on the remaining generation available in the islanded area. There will be an imbalance between generation and load in the islanded area. In most of the time there will be a deficiency of generation. So, the generators have to speed up with the help of spinning reserve available with them [4]. As a part of advanced monitoring and control there has to be enough spinning reserve in islanded system to tackle all the loads. This problem can be solved using the generator swing equation.

$$2H\omega = P_m - P_e = P_a \qquad (1)$$

Where H is the generator's inertia constant in seconds, P_m and P_e are respectively mechanical and electrical power , and ω is the electrical angular velocity or frequency in per unit values. Same equation can be written for having N machines in operation.

$$2H_{system}\omega_{system} = P_{m\_system} - P_{e\_system} = P_{a\_system} \qquad (2)$$

$$P_{a\_system} = \frac{2H_{system}}{f_n}\frac{df_{system}}{dt} \qquad (3)$$

Where H_{system}, P_{mi} and P_{ei} are based on system base VA $S_{Bsystem}$. The system inertia constant H_{system} can be defined in relation to system angular frequency ω_{system}, system mechanical power P_{m_system} and system electrical power P_{e_system}.

$$H_{system} = \sum_{i=1}^{N} H_i = \sum_{i=1}^{N} H_{machine}\left(\frac{S_{Bmachine}}{S_{Bsystem}}\right) \qquad (4)$$

$$\omega_{system} = \frac{\sum_{i=1}^{N}(H_i\omega_i)}{\sum_{i=1}^{N} Hi} \qquad (5)$$

$$P_{m\_system} = \sum_{i=1}^{N} P_{mi} \qquad (6)$$

$$P_{e\_system} = \sum_{i=1}^{N} P_{ei} \qquad (7)$$

Whenever there is a disturbance, the system accelerating power P_a consists of the disturbance P_D and the change in electrical power demand ΔP_e due to variation of the voltage and frequency. The accelerating power P_a is provided by the spinning reserve available with the generator.

$$P_a = P_D - \Delta P_e \qquad (8)$$

III. NETWORK MODELLING

The model used for this study shows the behavior of a synchronous generator connected with hydro turbine. It is assumed that the generator has enough spinning reserve to tackle all the load. A single generator feeding a fixed and isolated load is shown in Fig. 1. Here, two cases are simulated for the islanded system. (1) There is a deficiency of generation, so generator will speed up and (2) surplus of generation, so generator will slow down. A synchronous generator of 200 MVA is feeding into the grid. When the distribution network is islanded from the grid with the same generator as the only available generator the two cases mentioned above are simulated. Initially it was feeding a load of 50 MW, and at t = 5s it rises to 100 MW. In the second case, initially it was feeding a load of 100 MW and at t = 5s it decreases to 50 MW. Both the cases are feasible when the system is islanded.

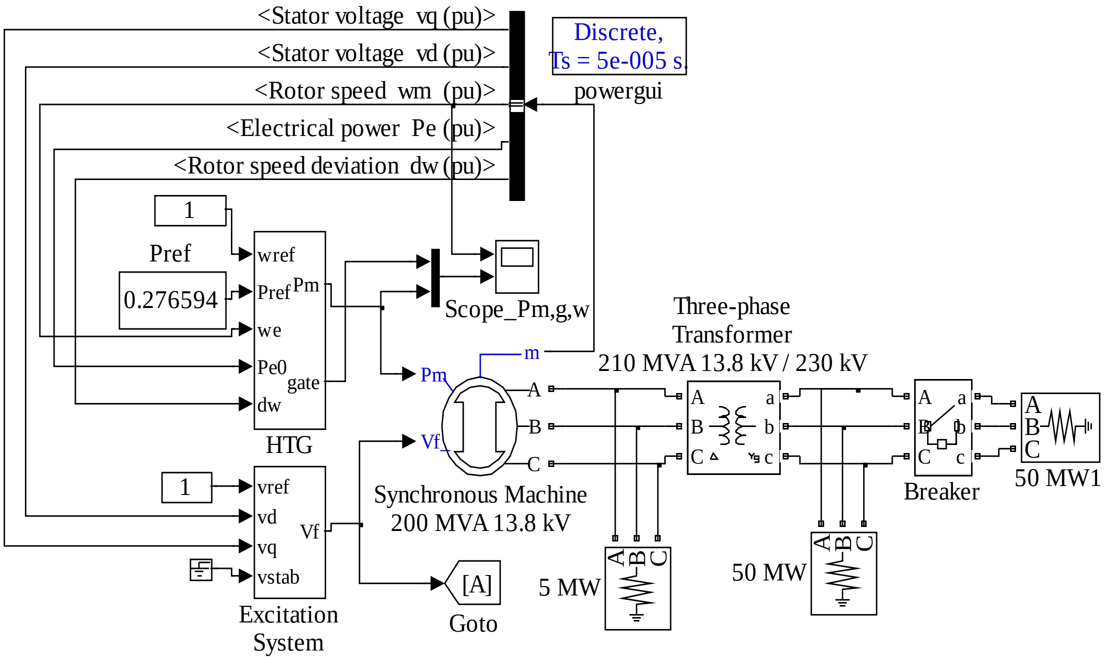


Fig. 1 Matlab/simulink model for islanding scenario

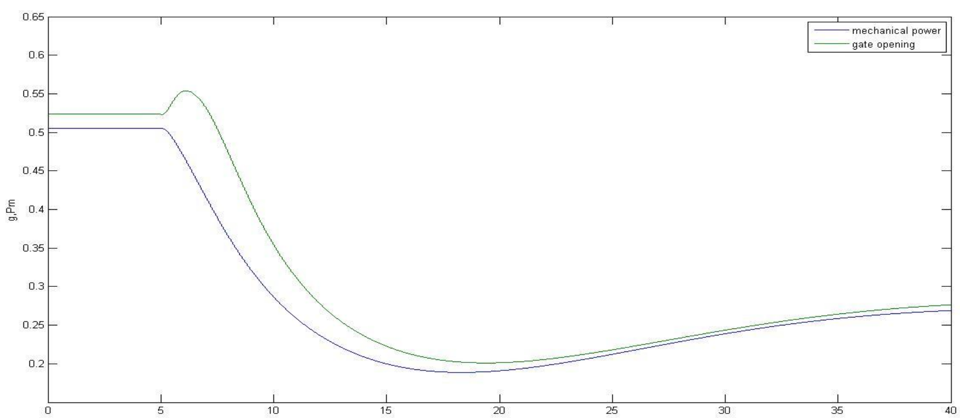


Fig. 2 Gate opening and mechanical power input to the generator

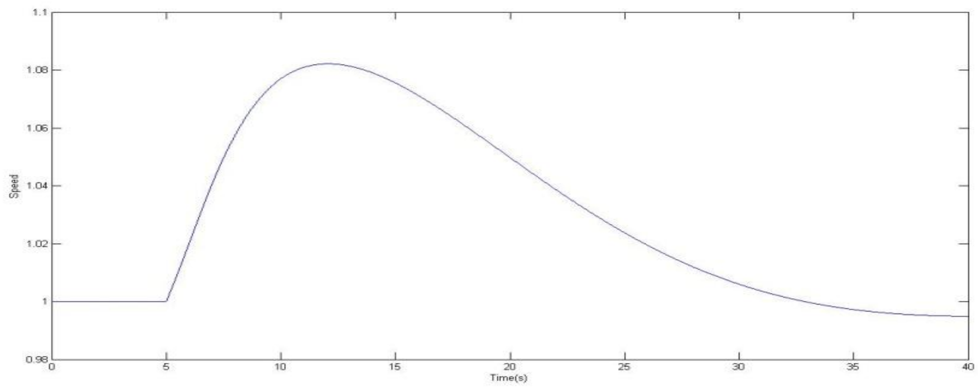


Fig. 3 Rotational speed of the turbine

As shown in Fig. 2. and Fig. 3 if the load is less after islanding, the mechanical power input to the turbine will get reduced and sucessively the generator output will also get reduced.

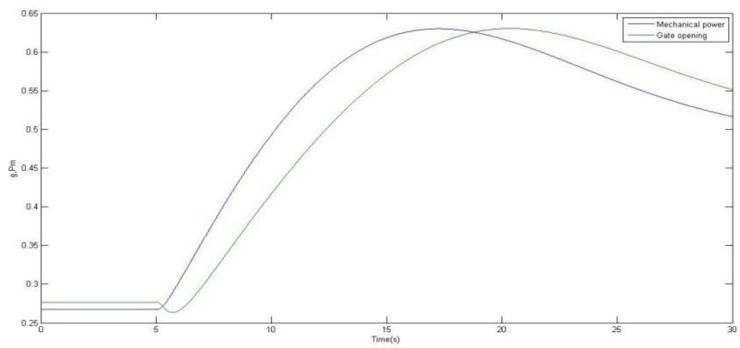


Fig. 4 Gate opening and mechanical power input to the generator

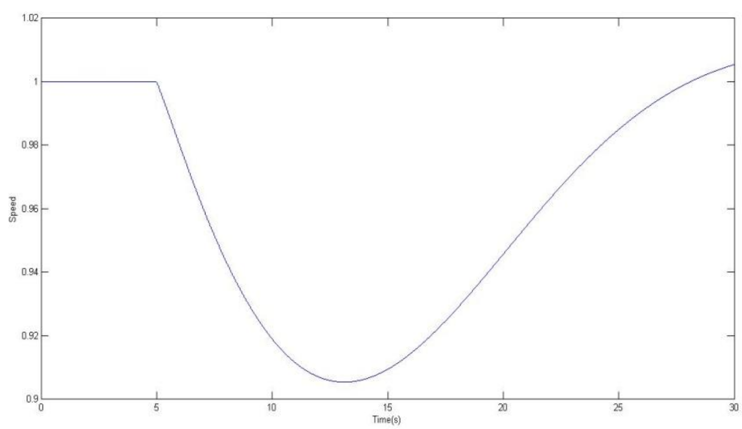


Fig. 5 Rotational speed of the turbine

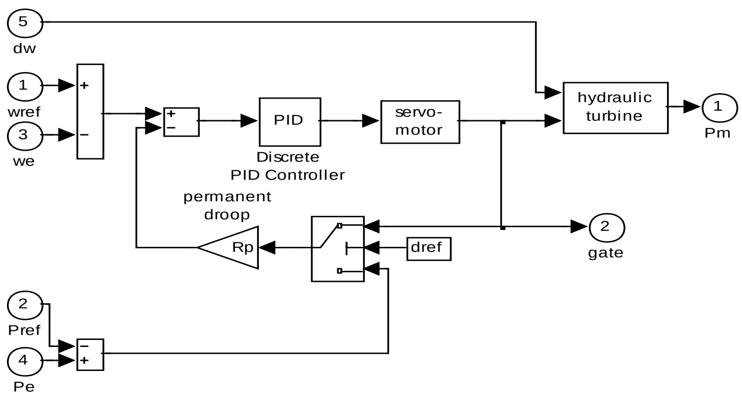
If the demand is high compared to available generation then the gate opening and mechaniacl power will increase hence generator will speed up as shown in Fig. 4. and Fig. 5.

IV. GENERATOR CONTROLLER

In islanding operation synchronous generator's governor plays an important role. A governor specifically performs the speed and active power control of the generator. Most of the plants utilize hydraulic mechanical governor. When it comes to islanded system, it is mandatory to use a governor with PID controller. The governor applied in this study is as shown in Fig. 6

[5]. The PID controller helps to maintain the stability of the islanded system. It is used to bring the speed/frequency and the voltage phasor as close as possible to their reference value.

The servomotor controls the gate position with the aid of the PID controller whose input is the difference between the reference ω_{ref} and actual ω_e turbine rotational speed. Two methods for droop characteristic realization are provided, depending on the binary signal d_{ref}. In the upper switch position, the gate position negative feedback is used; in the lower switch position, the droop depends on the difference between the generator electric power P_e and the reference value P_{ref}. If , for instance $P_e > P_{ref}$, the summer2 output >0 that appears as the negative one at the output of the summer 2 causes a decreases in the water flow and, consequently a decreases in turbine power. The controller output is mechanical power which is fed to the synchronous generator



The intentional islanding strategy is simulated on a test system. A simulation model is developed using the test system considering multiple generators in the islanded area as shown in figure. Two hydro synchronous generator units are equipped with a governor, a hydraulic turbine with all necessary valves for control of water flows. The distribution network is connected with transmission grid during normal operation. The total power required by the distribution network is fed by the transmission grid as well as the generators 1 and

2.

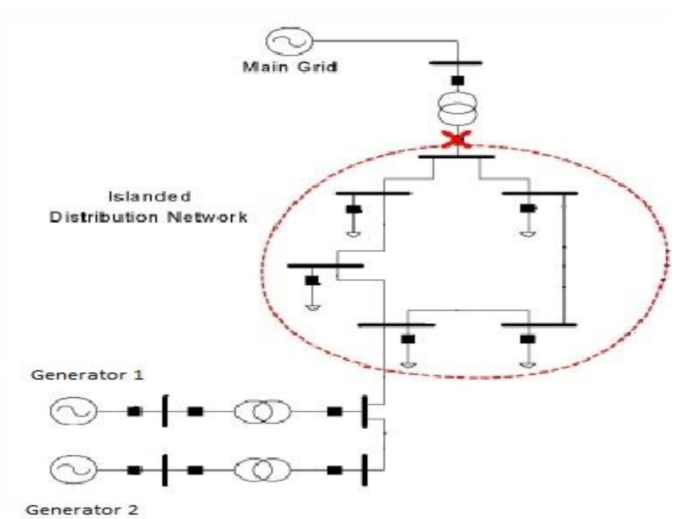
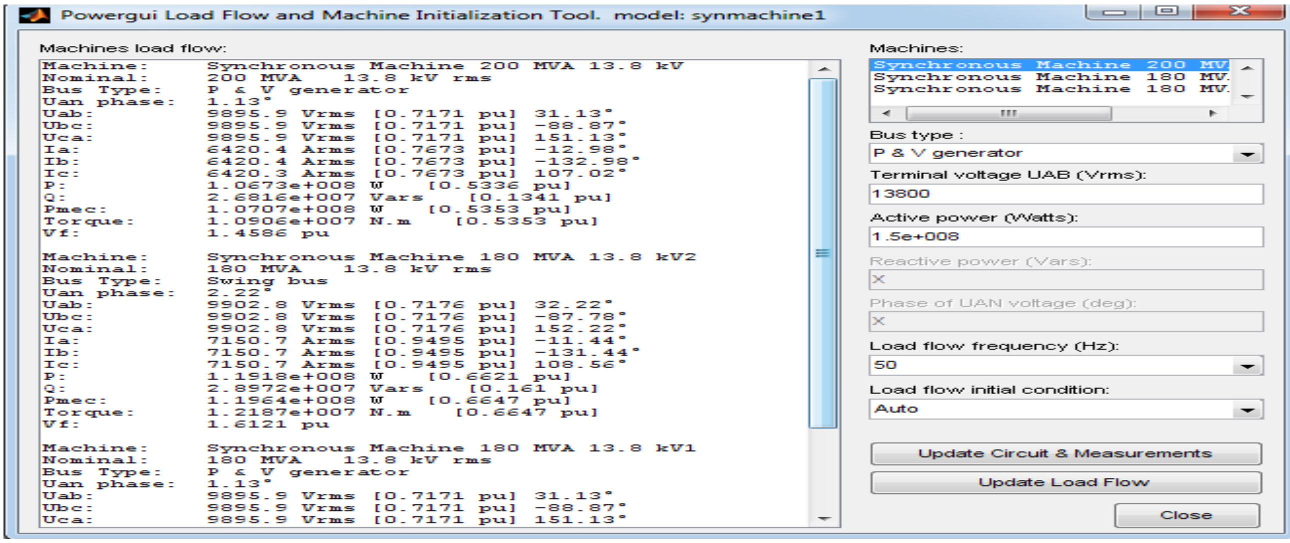


Fig. 8 Powergui load flow and machine initialization tool



Here, when the main grid is connected, the generators 1 and 2 are not run to their full capacity. For this purpose, Load Flow and Machine Initialization tool of Powergui block has been used. This tool permits commencing of simulation with steady state as shown in figure. The generator at the main grid is selected as a swing bus because it has highest generation amongst all the generators. But, when the distribution system is islanded due to disconnection of main grid, the remaining generators has to supply all the loads. So, for this purpose two swing bus are selected before commencing load flow. One swing bus is in the main grid and the other swing bus is from the generator 1 or generator 2 whoever is having the more generation. When the load flow is updated, the P_{ref} values at turbine governor will be updated in such a manner that generators 1 and 2 will not run to their maximum capacity. There will be a spinning reserve available at a generator where swing bus is selected. When the main grid is disconnected, the generator at swing bus 2 will take the responsibility to supply all the lost generation.

VI. RESULTS AND ANALYSIS

The simulation has been carried out when the main grid is connected and when the main grid is disconnected. It is observed from the figure that the system voltage remains constant when the main grid is connected. When the grid disconnects, all the load of distribution network has been tackled by the remaining generators. As shown in figure of voltage waveform, there is a momentary drop in voltage. As soon as the generator speeds up with the spinning reserve available with them the voltage will get back to its normal state.

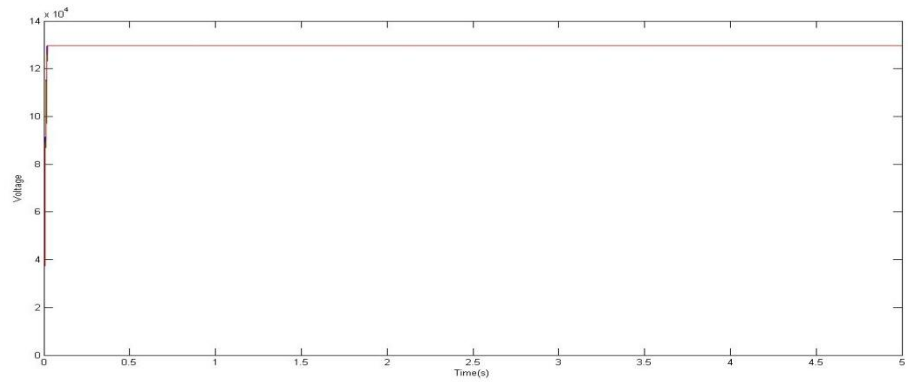


Fig. 9 Voltage response when main grid is connected.

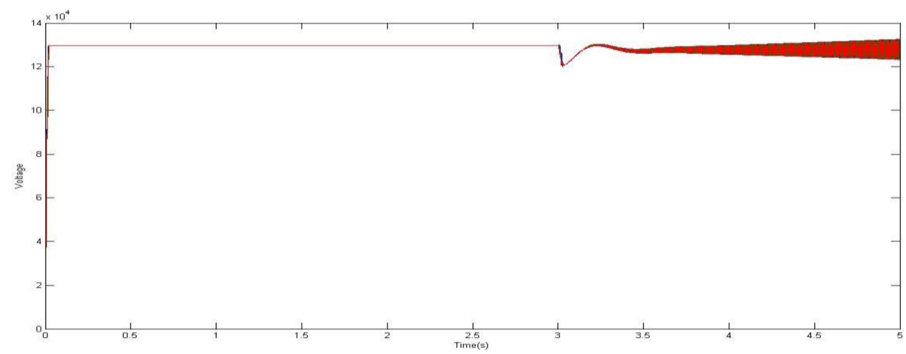


Fig. 10 Voltage response when the system is islanded.

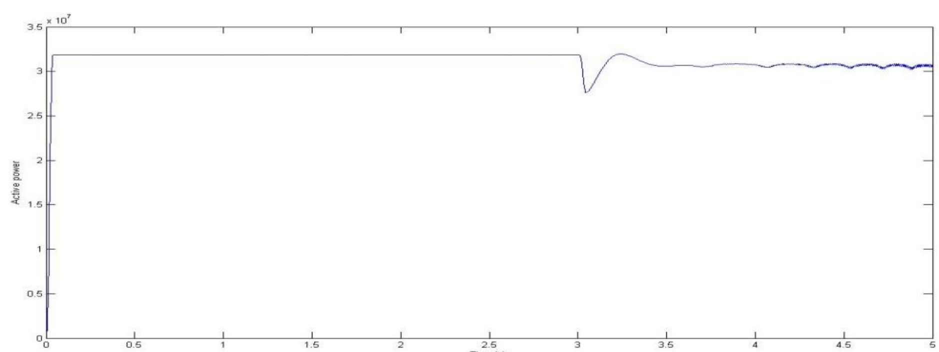


Fig. 11 Active power response when the system is islanded

VII. CONCLUSION

The concept of intentional islanding is shown in this paper. An essential requirement of this intentional islanding strategy requires advanced planning and monitoring. With the help of this, we can closely match the available generation to the connected load. If the planning and monitoring has not been carried out, then there will be a large mismatch between generation and load. In that case we have to shed some of the loads otherwise the island will collapse.

From the recent blackout in India it is observed that, the islands so created were not survived due to excessive loads [6]. So, the investigation report suggested implementing islanding scheme. It was also observed that the primary response from generators lacked timely response. This can be taken care by the generator controller shown in above simulation. A successful islanding operation can be achieved with the help of quick responsive generator controller and advanced planning and monitoring.

VIII. REFERENCES

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