21, rue d'Artois, F-75008 PARIS
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Synchrophasor Anti-islanding Scheme

Y. TANG
Virginia Tech
USA

R. SUN
Dominion Virginia Power
USA

K. THOMAS
Dominion Virginia Power
USA

SUMMARY

An islanding condition indicates a portion of loads and generators become isolated from the rest of the grid. The islanded area is susceptible to system stability and may come across severe power quality problems and reconnection problems. Islanding may occur in both distribution and transmission grids. Dominion Virginia Power's non-utility generators (NUGs) are equipped with anti-islanding scheme to trip the generators in islanded area.

As the existing anti-islanding schemes in DVP area are prone to human error, a new scheme is proposed using synchrophasor data for islanding detection. The proposed scheme makes use of the frequency difference measured by PMUs inside and outside the island.

PSS\E reduced model is built for the test-bed for the anti-islanding scheme area using dynamic equivalence and then converted to RSCAD to conduct real time simulation in RTDS. The threshold for the frequency deviation algorithm is set by an enumeration study of non-islanding disturbances . To test the feasibility and validity of proposed scheme, simulation is run for different contingencies and different generation states.

In sum, application of synchrophasor data in anti-islanding schemes helps to improve detection accuracy and improve system stability. The proposed scheme is capable of avoiding false tripping caused by inaccurate breaker/switch status and ride through all the non-islanding cases.

KEYWORDS

Anti-islanding, frequency deviation, generator protection, passive islanding detection, PMU, transmission power system.

yetang@vt.edu

1.Background Introduction

An islanding condition in power systems indicates that a portion of loads and generators become isolated from the main grid. It may occur in both distribution and transmission levels. The islanding area is susceptible to stability issues as the system inertia and capacity reduce. The islanding area may come across power quality issues like frequency oscillations and voltage deviations. Reconnection is another problem as the islanding region might be out of phase to the grid. Currently, Dominion Virginia Power (DVP) has implemented an islanding scheme/protection to trip the generators once the island is detected. This protection is majorly implemented for non-utility generation units (NUGs) in the DVP transmission system, as they are within areas where there is a reasonable possibility of islanding formation.

Fig.1 is a single line diagram to illustrate detection algorithm for the existing anti-islanding scheme in DVP. The anti-islanding scheme uses signals indicating open breakers or open switches to detect system topology. In this scheme, the isolation from the left side is detected if left remote breaker, the network radial switch is in radial position, or the circuit breaker 3 is open. The network radial switch is manually set by operators or technicians. The isolation from the right side is detected in the same way. The anti-islanding scheme will be triggered immediately once isolation is detected on both sides.

The main risk of this detection method is the human interaction in operating the network radial switches and in setting for the maintenance status of breakers. In a few cases, human errors have caused false operations and unplanned generator disconnections

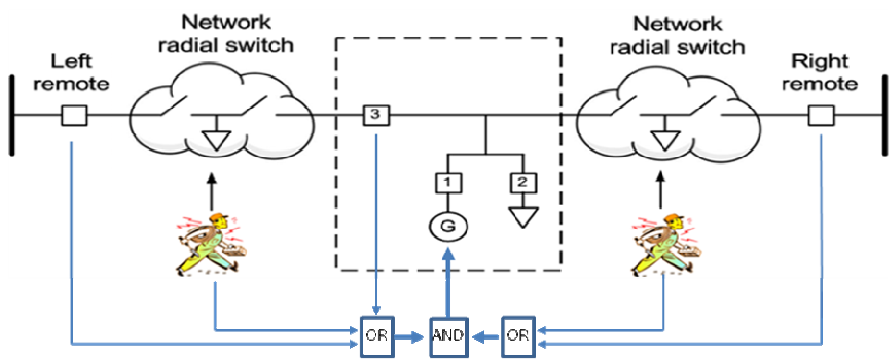


Fig.1 Detection algorithm of existing anti-islanding schemes in DVP

A lot of research of has been done about anti-islanding in distributed system [1,2], but not much has been done with the application of PMU [3,4] in anti-islanding scheme in transmission system. The goal of this project is to develop a hybrid anti-islanding scheme combining PMU data and original breaker/switch signals to achieve more accurate islanding detection. Real time digital simulator (RTDS) is used to prove the feasibility of the scheme.

In this paper, section 2 introduces test-bed topology and modelling in PSS/E and RSCAD. Section 3 is the design of proposed islanding detection algorithm using PMU data. Section 4 shows the simulations results to compare previous scheme and proposed scheme, followed by section 5 of conclusions.

2. Test-bed Introduction

One existing anti-islanding scheme covered area in Dominion is chosen as the test-bed (shown in Fig.2). The existing scheme starts from substation A, passes non-utility generator stations F and G, and stops at the substation of I. Substation A, E and I are the three boundaries of this islanding area. The total generation is 685MW and total load is 115MW in summer peak. Complexity is the major reason for the selection - 9 substations and 3 tap stations are involved. And another important reason is that Dominion has already installed phasor measurement unit (PMU) s at 500kV substations.

The existing anti-islanding scheme is not complete, as it only takes 230kV breakers and switches into consideration in islanding detection. However, there is a 115kV line (line 3) that connects this area with the rest of grid. The existing scheme assumes that line 3 is not able to export so much power from the isolated generators once both 230kV lines are off. To validate this assumption, a dynamic simulation is done in PSS/E using the MMWG Eastern Interconnection model with 2015 summer peak load condition . Test results show that with generators at maximum output, line 3 will be tripped by line protective relays; if there's significant generation curtailment, line 3 will stay in. The existing scheme will trip off the generators regardless the status of line 3, even if the system is not physically islanded. In contrast, the proposed anti-islanding scheme doesn't need to take specific consideration of the 115kV line, because it utilizes frequency measurements to recognize whether this area has been really islanded or not.

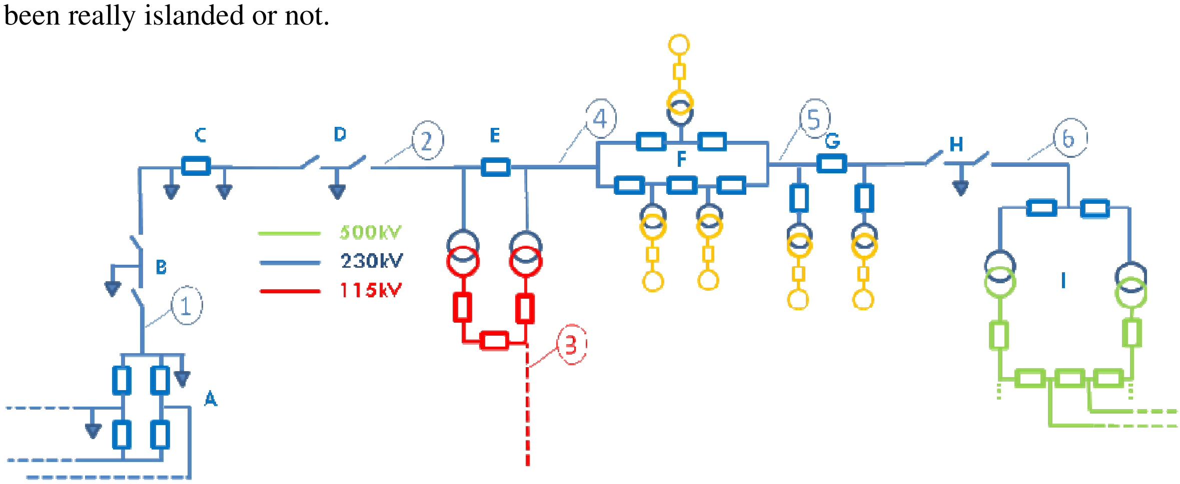


Fig.2 Anti-islanding scheme test-bed one line diagram

We have tested the scheme on real time digital simulator (RTDS) – a multi-processor system that can simulate power system in real time and interact with hardware devices. However RTDS can only model limited number of buses and devices. So it is necessary to apply dynamic equivalence for the full model to create a reduced model for our study.

The equivalence process keeps internal components and boundary buses unchanged, extends one bus away from these boundary buses, then eliminates all the external components. The external parts are represented by virtual generators and virtual loads. Network elimination is done by PSS\E network equivalence function . The virtual generator inner impedances are from ASPEN protection model equivalence. Virtual generator dynamic models are tuned by comparing frequency response of the reduced system model and the full model. The reduced system model in PSS\E is then converted to the RTDS model. Breakers, switches and disturbance control modules are added in to control the system in real time simulation.

3. Frequency Deviation Islanding Detection Algorithm

The proposed anti-islanding scheme uses frequency deviation as islanding detection criteria. When islanding occurs, the unbalance of generation and load will deviate the frequency from 60Hz in the island. Frequency of the external grid maintains frequency close to 60 Hz because of high inertia. The frequency difference in and out of the island will gradually increase. 0.1s of time delay need to be added to the frequency deviation algorithm because of the unreliable PMU data during fault transient. As an example shown in Fig.3, a three phase to ground fault occurs at line 4 and is isolated after 4 cycles. And because PMU uses 2 cycles of data to calculate the frequency output, the PMU frequency measurements are inaccurate compared with the actual generator rotating speed for 6 cycles, which need to be ride through.

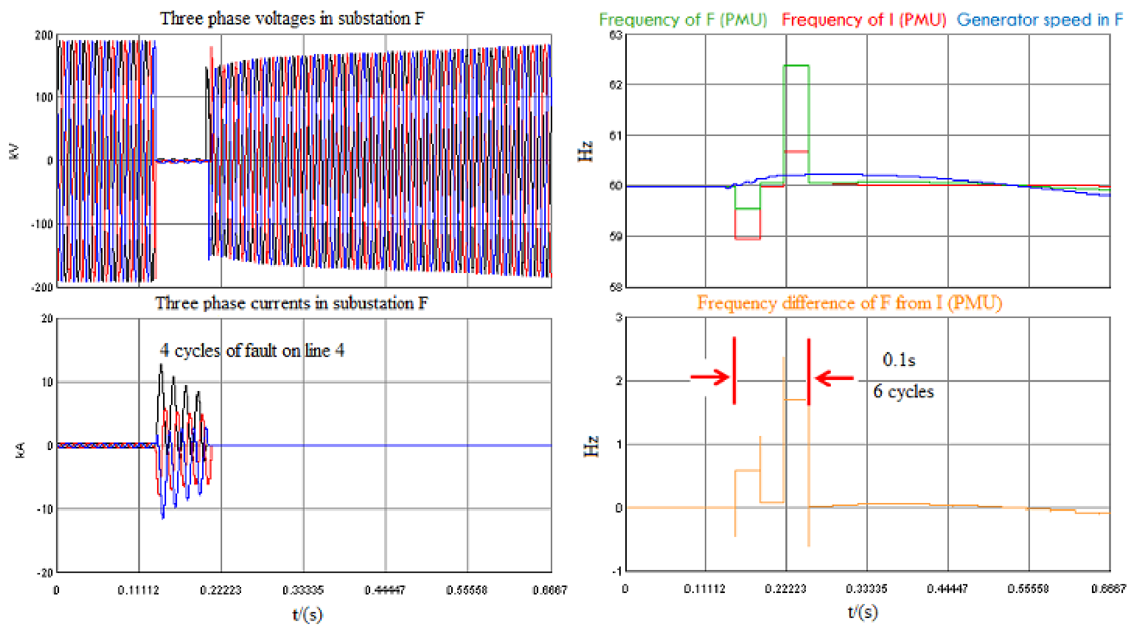


Fig.3 Fault transient on line 4

The threshold of frequency is set to ride through all non-islanding disturbances. These disturbances include (1) normal line switching operations (2) faults on one line (3) both 230kV paths open but 115kV line 3 is not tripped and (4) Line 4/5/6 is in radial position, and line 1 or 2 (on the left) is tripped by a fault but reconnected by instant reclosing before line 3 tripped by distance relay as described by section 2. Simulation results show that biggest disturbance is (4) and the frequency response is shown on Fig.4, according to which frequency threshold is set to 1 Hz and time delay is 0.1 s.

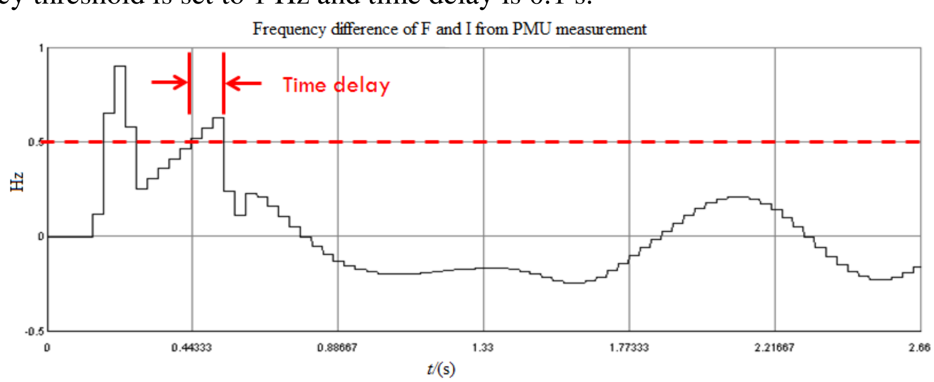


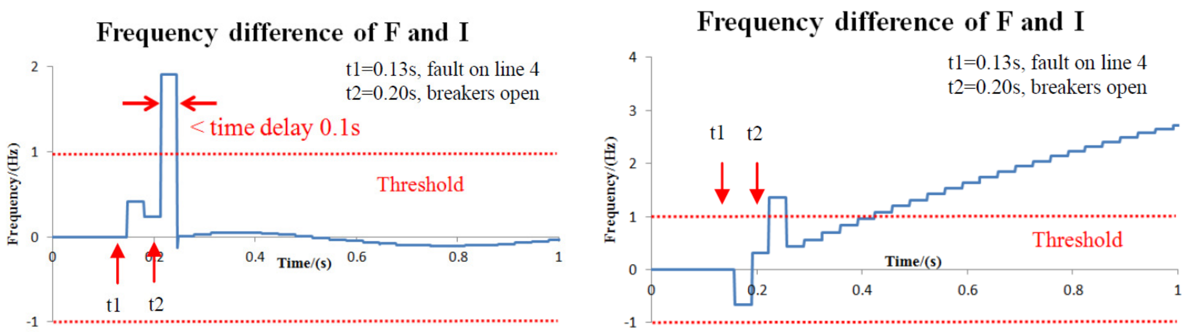
Fig.4 Frequency difference of F and I under biggest disturbance

4. Simulation Results

To test the islanding detection accuracy and the speed of the proposed anti-islanding scheme, cases of different contingencies and generator operation states are simulated in RTDS testbed. Several examples are selected to be introduced below to demonstrate the scheme's performance. .

4.1 Comparison of proposed scheme results on islanding and non-islanding cases

Fig.5 shows frequency difference of F and I measured by PMU of two cases. The disturbance of case 1 is a three phase temporary fault (t = 0.1333s-0.2s) on line 4 which doesn't cause islanding. In case 2, the breaker in substation G which connects line 5 and line 6 is already open for maintenance, and then a fault occurs line 4 (t = 0.1333s-0.2s) which leads to islanding. In Fig.5 (a), proposed anti-islanding scheme is not triggered because the time for frequency deviation is less than time delay 0.1s. In Fig.5 (b), proposed anti-islanding scheme is triggered correctly due to a detection of frequency over threshold after 0.1 second.



(a) (b)

Fig.5 frequency different of F and I in (a) non-islanding case and (b) islanding case

4.2 Comparison of existing and proposed anti-islanding schemes on non-islanding cases

Compared to the existing anti-islanding scheme, proposed anti-islanding scheme is able to avoid wrong tripping of generators caused by human error. In case 1 of table I, the network/radial switch for line 6 is at the wrong position of radial, and the breaker in G that connects line 5 and 6 is disconnected in operation, the existing scheme is triggered immediately and trips some of generators in G, while proposed scheme is not triggered as all the generators are still operating in synchronization with the grid.

In case 2 in table I, part of generators in substation F are modelled offline to indicate a curtailment condition. Line 3 stays in after line 1 and line 6 are open. In this case existing anti-islanding scheme trips all the generators because only the status of 230kV breakers and switches is taken into consideration. But proposed scheme is able to detect that the generators are not islanded by assessing the frequency measurement data.

Table I Results of existing and proposed schemes in two non-islanding cases

Case number	Description	Existing scheme	Proposed scheme
1	Human error	Trip the generators	Doesn't trip the generators
2	Curtailed generation	Trip the generators	Doesn't trip the generators

4.3Comparison of existing and proposed anti-islanding schemes in detection speed

In islanding cases, existing scheme will be triggered immediately once islanding occurs, but the proposed scheme will wait until frequency difference is above threshold longer than 0.1 s. The delay of proposed scheme compared to existing scheme varies in different cases.

The shortest delay in all case tested is 0.33s , resulting from the case that right part of generator in substation G is isolated by relay after a temporary fault in line 6. And the longest delay is 1.52swith the case that only the smallest generator is in operation, and line 4 and line 6 is open. The generation capacity is 37MW and total load is 24MW in this most balanced island.

5. Conclusion

As the existing anti-islanding scheme in DVP area is prone to human error, a new scheme is proposed using synchrophasor data for islanding detection. The proposed scheme makes use of frequency difference measured by PMU inside and outside the island.

PSS\E reduced model is built for the test-bed of the anti-islanding scheme area using dynamic equivalence and then converted to RTDS for real time simulation analysis. The threshold for the frequency deviation algorithm is set by the largest non-islanding disturbance. To test the feasibility and validity of proposed scheme, simulation is run for different contingencies and different generation states.

In sum, the application of synchrophasor data in anti-islanding scheme helps to improve detection accuracy and improve system stability. The proposed scheme is capable of avoiding false tripping caused by inaccurate breaker/switch status and ride through all the non-islanding cases.

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