IJIREEICE ISSN (O) 2321-2004, ISSN (P) 2321-5526

International Journal of Innovative Research in Electrical, Electronics, Instrumentation and Control Engineering

ISO 3297:2007 Certified ∺ Impact Factor 7.12 ∺ Vol. 10, Issue 12, December 2022

DOI: 10.17148/IJIREEICE.2022.101208

# ISLANDING DETECTION USING ON GRID ACTIVE AND REACTIVE POWER

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**Abstract:** In increasing development of world, the “electricity or electrical power” plays main role. For this delivering the continuous power is necessary. In this report we will discuss about situation of islanding in which local load disconnected from main grid or micro grid and connected with source of distributed power generation. Distributed generations like PV cells, wind turbines etc. gives the continuous power supply to the load and protect it from the interruption. When load disconnected from grid and connect with DG set, for this some islanding detection methods are used which is active method, passive method and utility based method and some advanced detection method for islanding.

**Keywords :** Distributed Generator ,Islanding Condition , Islanding Detection Methods , Advance Anti-Islanding Protection , Wind Farm , Local Load , STATCOM , Grid Connecting Transformer,B25 Bus Data Acquisition

## I. INTRODUCTION

As world is developing day by day, Demand of electrical power is also rising with it. An example of an electric power system is the network that supplies a region's homes and industry with power—for sizeable regions, this power system is known as the grid and can be broadly divided into the generators that supply the power, the transmission system that carries the power from the generating centers to the load centers and the distribution system that feeds the power to nearby homes and industries.

To meet the electricity demand, more and more power generators are used to generate electricity and transmission lines to supply power to the consumer end and distribution of electricity at consumer becomes more complicated. Power generators can generate power at different voltage levels and frequency. Consumers require to use equipment as voltage level and frequency of their power. So power system standards are made by Indian government.

As standards, 11kv is generating voltage level and 50Hz is frequency. Now all individual micro-grids can be connected to each other and forms a huge grid all over the India to maintain same voltage level and frequency of power system. Power system or grid consists of power plants, transmission lines, distribution network and protective equipment in case any fault occurs in it.

There are nuclear power station, thermal power station, solar power station solar-thermal power station, wind power station; diesel generators, hydro power plant etc. are used to generate electricity. Solar power station, wind power station, Diesel generators and other small capacity plants are used to supply power to small area or village or separate building.).

## II. DISTRIBUTED GENERATORS

Distributed generation (or DG) generally refers to small-scale (typically 1 kW – 50 MW) electric power generators that produce electricity at a site close to customers or that are tied to an electric distribution system. Distributed generators include, but are not limited to synchronous generators, induction generators, reciprocating engines, micro turbines (combustion turbines that run on high-energy fossil fuels such as oil, propane, natural gas, gasoline or diesel), combustion gas turbines, fuel cells, solar photovoltaic, and wind turbines.

## III. APPLICATION OF DISTRIBUTED GENERATORS

There are many reasons a customer may choose to install a distributed generator. DG can be used to generate a customer’s entire electricity supply; for peak shaving (generating a portion of a customer’s electricity onsite to reduce the amount of electricity purchased during peak price periods); for standby or emergency generation (as a backup to Wires Owner's power supply); as a green power source (using renewable technology); or for increased reliability. In some remote locations, DG can be less costly as it eliminates the need for expensive construction of distribution and/or transmission lines.

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## IV. ISLANDING CONDITION

Islanding refers to the condition in which a distributed generator (DG) continues to power a location even though electrical grid power from the electric utility is no longer present. The common example of islanding is a grid supply line that has solar panels attached to it. In the case of a blackout, the solar panels will continue to deliver power as long as irradiance is sufficient. In this case, the supply line becomes an "island" with power surrounded by a "sea" of unpowered lines. For this reason, solar inverters that are designed to supply power to the grid are generally required to have some sort of automatic anti-islanding circuitry in them. In intentional islanding, the generator disconnects from the grid, and forces the distributed generator to power the local circuit. This is often used as a power backup system for buildings that normally sell their excess power to the grid.There are two type of islanding, i.e. intentional islanding and un-intentional islanding. In case of intentional islanding, when the maintenance is necessary for the specific part or portion of micro-grid and it is disconnected from main grid it's called Intentional Islanding. Where in un-intentional islanding, it is not planned to disconnect intentionally but it disconnects due to any types of fault.

### IMPACT OF ISLANDING:

We have already understood what islanding is, Lots of methods have been developed to detect islanding until now. It is important to consider whether or not the problem actually demands the amount of effort being expended. Generally speaking, the reasons for anti-islanding are given as below

### SAFETY CONCERN:

The first issue has been widely dismissed by many in the power industry. Line workers are already constantly exposed to unexpectedly live wires in the course of normal events (i.e. is a house blacked out because it has no power, or because they pulled the main breaker inside?). Normal operating procedures under hot-line rules or dead-line rules require line workers to test for power as a matter of course, and it has been calculated that active islands would add a negligible risk. However, other emergency workers may not have time to do a line check, and these issues have been extensively explored using risk-analysis tools. This may confuse the utility workers and expose them to hazards such as shocks.

### DAMAGE TO CUSTOMER'S APPLIANCES:

Due to islanding and distributed generation, there may a bi-directional flow of electricity. This may cause severe damage to electrical equipment, appliances and devices. Some devices are more sensitive to voltage fluctuations than others and should always be equipped with surge protectors also they are sensitive to the frequency fluctuation so change in frequency also harm customer's appliances.

### INVERTER DAMAGE:

In the case of large solar systems, several inverters are installed with the distributed generators. Recloses are commonly used to divide up the grid into smaller sections that will automatically, and quickly, re-energize the branch as soon as the fault condition (a tree branch on lines for instance) clears. There is some concern that the recloses may not re-energize in the case of an island, or that the rapid cycling they cause might interfere with the ability of the DG system to match the grid again after the fault clears. Reclosing the circuit onto an active island may cause problems with the utility's equipment, or cause automatic reclosing systems to fail to notice the problem. Reclosing onto an active island may cause confusion among the inverters.

## V. ISLANDING DETECTION METHODS

As we have seen Islanding detection can be done with the help of active islanding methods and passive islanding methods at DG level.

### PASSIVE ISLANDING METHODS

Passive detection methods, on the other hand, make use of transients in the electricity (such as voltage, current, frequency, etc.) for detection.

### 1. UNDER/OVER VOLTAGE

According to Ohm's law, the voltage in an electrical circuit is a function of electric current (the supply of electrons) and the applied load (resistance). In the case of a grid interruption, the current being supplied by the local source is unlikely to match the load so perfectly as to be able to maintain a constant voltage. A system that periodically samples voltage and looks for sudden changes can be used to detect a fault condition.

  

IJIREEICE

ISSN (O) 2321-2004, ISSN (P) 2321-5526

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## 2. UNDER/OVER FREQUENCY

The frequency of the power being delivered to the grid is a function of the supply, one that the inverters carefully match. When the grid source is lost, the frequency of the power would fall to the natural resonant frequency of the circuits in the island. Looking for changes in this frequency, like voltage, is easy to implement using already required functionality, and for this reason almost all inverters also look for fault conditions using this method as well.

The combination of voltage and frequency shifts still results in a NDZ that is not considered adequate by all.

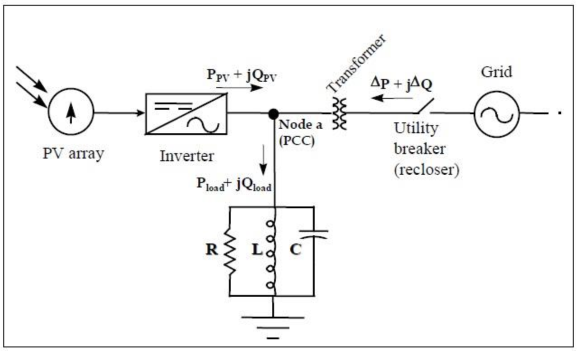



Fig.-Utility configuration showing power flow and terminology

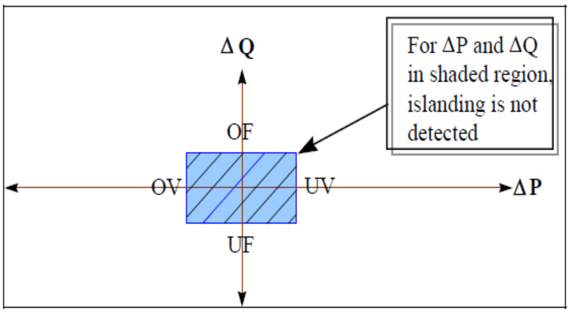
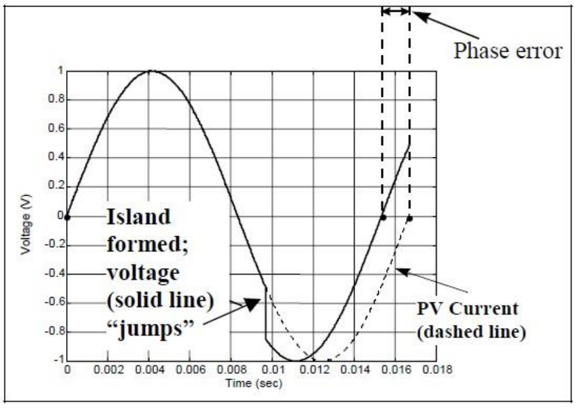



Fig.- Mapping of the NDZ in ΔP Versus ΔQ Space for Over/under Voltage and Over/under Frequency

## 3. VOLTAGE PHASE JUMP DETECTION

Loads generally have power factors that are not perfect, meaning that they do not accept the voltage from the grid perfectly, but impede it slightly. Grid-tie inverters, by definition, have power factors of 1.

This can lead to changes in phase when the grid fails, which can be used to detect islanding.




Fig–Phase voltage jump detection method

IJIREEICE ISSN (O) 2321-2004, ISSN (P) 2321-5526

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## 4. HARMONICS DETECTION

Even with noisy sources, like motors, the total harmonic distortion (THD) of a grid-connected circuit is generally unmeasurable due to the essentially infinite capacity of the grid that filters these events out. Inverters, on the other hand, generally have much larger distortions, as much as 5% THD. This is a function of their construction; some THD is a natural side-effect of the switched-mode power supply circuits most inverters are based on.

## ACTIVE ISLANDING METHODS

Active methods generally attempt to detect a grid failure by injecting small signals into the line, and then detecting whether or not the signal changes.

Frequency bias forces a slightly off-frequency signal into the grid, but "fixes" this at the end of every cycle by jumping back into phase when the voltage passes zero. This creates a signal similar to Slip Mode, but the power factor remains closer to that of the grid's, and resets itself every cycle. Moreover, the signal is less likely to be filtered out by known loads. The main disadvantage is that every inverter would have to agree to shift the signal back to zero at the same point on the cycle, say as the voltage crosses back to zero, otherwise different inverters will force the signal in different directions and filter it out.

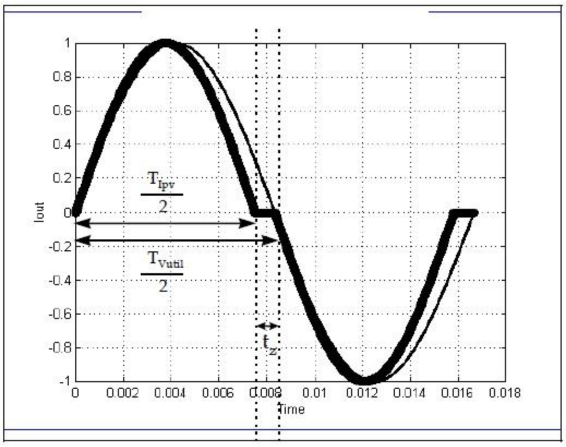


Fig: Example of a Waveform used to Implement the Frequency Bias Method of Islanding Detection

## UTILITY-BASED METHODS

The utility also has a variety of methods available to it to force systems offline in the event of a failure other than active and passive islanding methods.

## VI. ADVANCED ANTI-ISLANDING PROTECTION

Now a day, there are lots of advanced methods are introduced to detect islanding condition which are very accurate and reliable.

## COMBINED CHANGES OF ACTIVE AND REACTIVE OUTPUT POWERS OF DISTRIBUTED GENERATIONS

Anti-islanding protection is islanding detection based on output active power changes of the DG's terminal. The performance of the algorithm is based on instantaneous measurement of the output power. In cases that system is lost, a change in DG's loading is happened and its instantaneous output power is changing. In this case by measuring the DG's output power this state could be detected. The instantaneous output power is measured as follows:

$$P_{DG} = |v_a||i_a|\cos(\theta_a) + |v_b||i_b|\cos(\theta_b) + |v_c||i_c|\cos(\theta_c) \qquad (1)$$

Where

Va, Vb, Vc are sampling values of the output voltages and ia, ib, ic are sampling values which are measured in the output lines of DG. By this measurement and deriving of it, output power changes could be calculated.in the method, active power is measured from the Eq. (1) and then output reactive power is calculated instantaneously by measuring the voltages and currents. If their values are less than threshold, system will continue to work. But if the active power is more

  

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than threshold, reactive power value is considered and if its value exceeds threshold so islanding is detected and disconnect command will be transmitted.

As Research done on below test system and its parameter is shown in table,

| Parameter | Value |
|---|---|
| Turbine Rated Power | 660KVA |
| $R_s$ | 1Ω |
| $L_s$ | 1mH |
| Rated Voltage of Local Load | 0.4 KV |
| Nominal Grid Voltage | 20KV |
| Transformer Voltage Ratio | 0.4/20KV |
| Transformer Rated Power | 660KVA |
| Frequency | 50Hz |

Table Parameters of test system

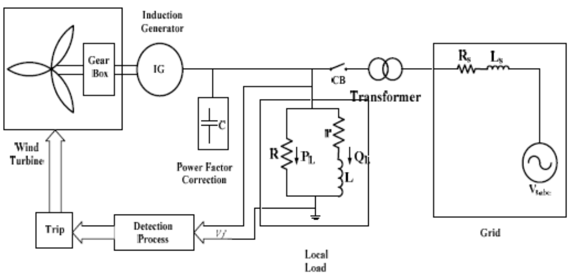


Fig. Test system to detect islanding conditions, including local load,power network, wind turbine

**Algorithm of test system**

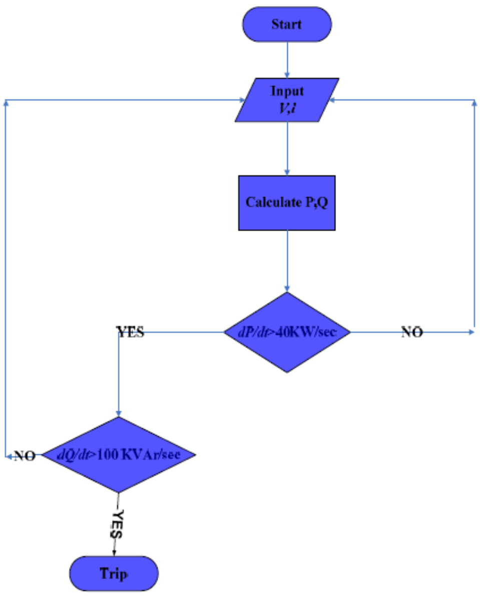


Fig .Proposed algorithm to detect island

For different system threshold value of change in active power and reactive power. There are 2 load conditions,

- When generated power doesn't match to load power.
- When generated power exactly match to load power.

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- **GRAPH OF POWER AND RATE OF POWERS FOR TEST SYSTEM**

At t=5 second, Islanding occurs,

During Load condition-1

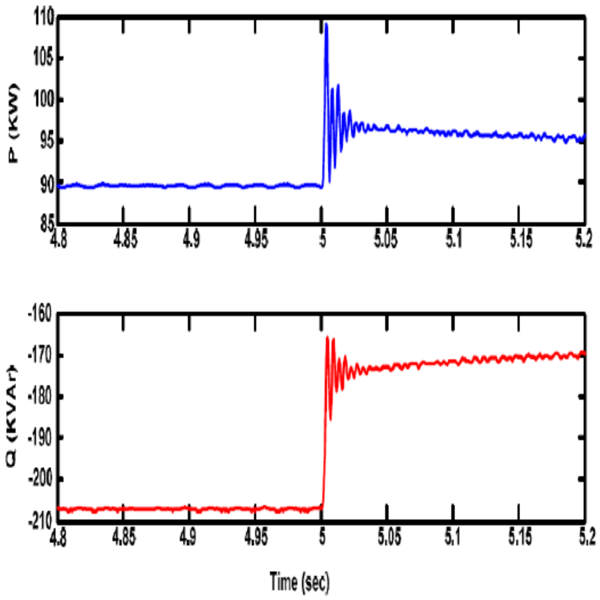


Fig. Output active power of DG and reactive power of DG

As shown in fig When islanding occurs, Output of Generator active and reactive power are increased transiently and after some time they matches load power.

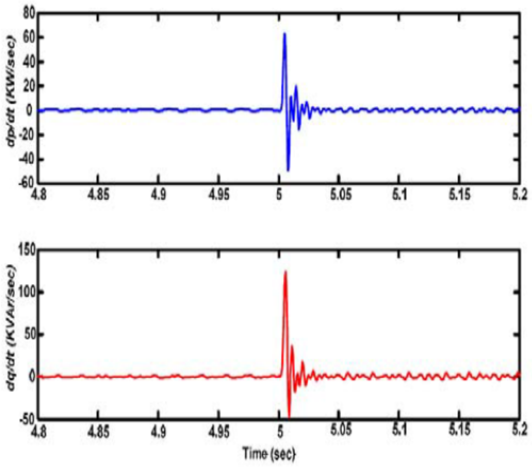


Fig. Output active power changes of DG and reactive power changes of dg

As shown in fig before islanding, Output of Generator active power changes and reactive power changes almost zero and when islanding occurs, transient signal is generated and their amplitude goes beyond 50 units and after sometime they again gain steady state condition.

During Load condition-2

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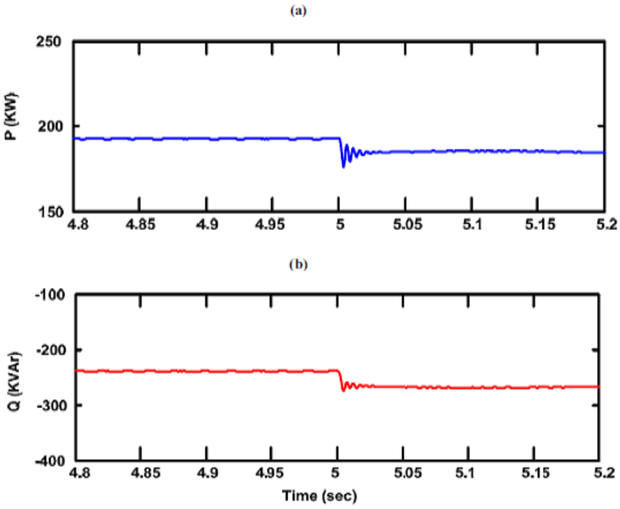


Fig. Output active power of DG
Fig. Output reactive power of DG

During load condition 2, change of output power of DG is less than load condition-1 when-Islanding-occurs.

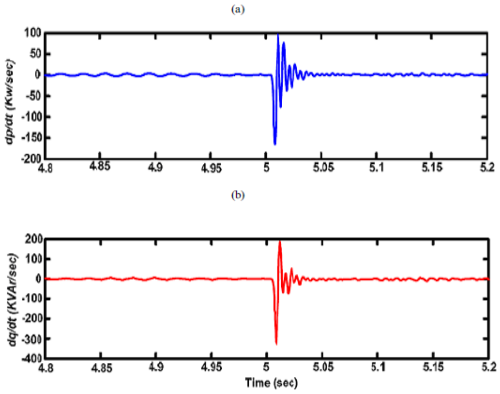


Fig. Output active power changes of DG
Fig. Output reactive power changes of DG

As shown in fig and Before islanding, Output of Generator active power changes and reactive power changes almost zero and when islanding occurs, transient signal is generated and their amplitude goes beyond 50 units and after sometime they again gain steady state condition.

Connecting Capacitor bank and Starting motor are also makes change to rate of output active and reactive power of DG but choosing appropriate threshold value, they can be isolated.

## SIMULATION MODEL AND EXPLAINATION

Now a day, there are a lot of computer simulation software like Open Sim, PSim, MATLAB etc. MATLAB have large library of different blocks, used to simulate model and wide area of availability of required block for different systems. MATLAB is also popular software and most of the scientist prefer to simulate their system on MATLAB before executing in real life so they can know results without spending a lot of cash on equipment for system and can check outcomes of their system. We have also chosen to simulate our model on MATLAB.

To apply islanding detection, we have taken 9MW wind-farm generating at 575 V line to line rms voltage at 60 Hz frequency. Which is supplying power to load at 25kV and Connected to grid having 120kV line to line rms voltage through transformer Islanding detection system is applied to that system based on combined change of active and reactive output power of distributed generators. VI measurement block measures voltage and current and using them, power is

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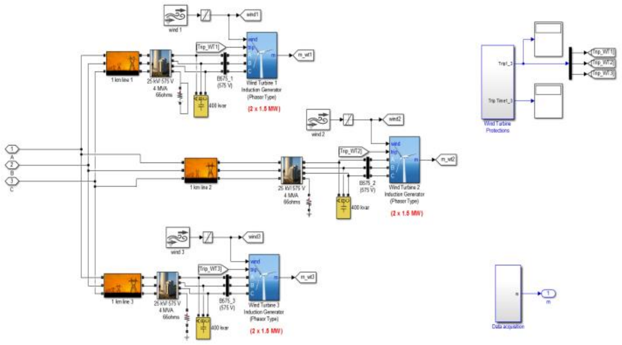
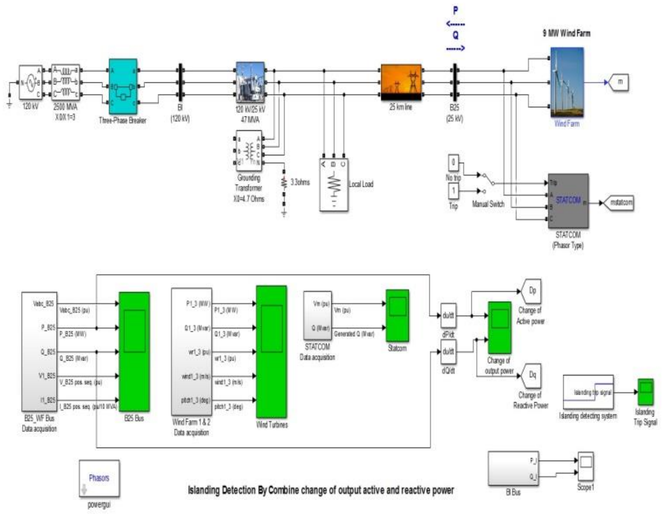
calculated and by derivative of that change of power is achieved. Thresholds are taken from IEEE research paper which are working well on our system too.



**WIND FARM:-**
We have taken wind power system generating 9MW. There are three phasor type wind turbine induction generators, each turbine generates (2*1.5) MW at 60Hz frequency. The power factor is taken 0.9. We have implemented a phasor model of a squirrel cage induction generator driven by wind turbine.

**LOCAL LOAD :-**
Local load is connected to wind farm 25 km far so 25km long transmission line block is placed there for transmission of power system and as we know transmitting power at high voltage results in low transmission line losses and have higher efficiency and also local load is connected to Grid. Load is RL series load. During islanding condition, local load is directly connected to wind farm.




**STATCOM : -**

The Static Synchronous Compensator (STATCOM) is a shunt device of the Flexible AC Transmission Systems (FACTS) family using power electronics to control power flow and improve transient stability on power grids.

The STATCOM regulates voltage at its terminal by controlling the amount of reactive power injected into or absorbed from the power system. When system voltage is low, the STATCOM generates reactive power (STATCOM capacitive).

When system voltage is high, it absorbs reactive power (STATCOM inductive).it is three phase. It is connected with wind farm output lines. it is provided with manual switch for switching of STATCOM. when the system is not tripped that time it is open through switch and it's becomes 0.

When the system is tripped that time switch is closed and it's becomes 1.

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| | |
|---|---|
| V | Positive sequence voltage (pu) |
| I | Reactive current (pu/Pnom) (I > 0 indicates an inductive current) |
| Xs | Slope or droop reactance (pu/Pnom) |
| Pnom | Three-phase nominal power of the converter specified in the block dialog box |

**GRID CONNECTING TRANSFORMER :-**

Grid is at 120kV voltage and wind farm supplying power at 25 kV. So a transformer is required to connect both of them. Transformer power rating is 47 MVA.

**GRID**

Grid is constructed here with 2500 MVA and 120kV voltage source. It is connected to wind farm system using normally closed circuit breaker which is opened at 10 sec simulation time to generate islanding condition.

**GROUNDING TRANSFORMER:-**

It is used to provide zero sequence current path on delta winding connection and also used to create neutral point on delta side. They are also used to limit fault currents. Grounding transformer are typically used to :

- Provide a relatively low-impedance path to ground, thereby maintaining the system neutral at or near ground potential.
- Limit the magnitude of transient over voltages when restriping ground faults occur.
- Provide a source of ground fault current during line-to-ground faults.
- Permit the connection of phase-to-neutral loads when desired.

**B25 BUS DATA ACQUISITION:-**

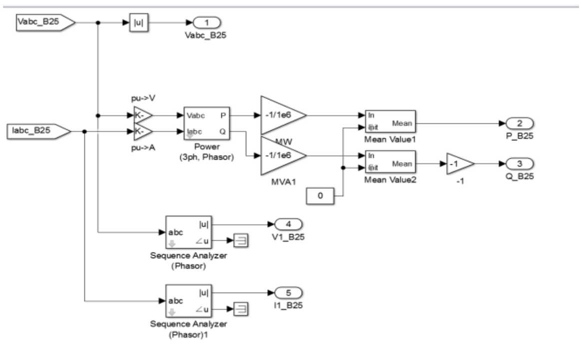


Fig.B25 bus data acquisition

This subsystem is used to calculate power, voltage, current, positive sequence voltage(in pu) and positive sequence current(in pu).In this only the magnitude of $V_{abc}$ (pu) and $I_{abc}$ (pu) is taken from V-I measurement block(B25). Using those measurement, True Power is calculated in complex and from that active and reactive power is taken.

V-I measurement block measures rms voltage phase to ground in pu and rms current in phase in pu with base voltage of 25 kV and base power 10 MVA.

For maximum line to line voltage calculation below formula is used.

$$V_m = \frac{\sqrt{2} \times V_{rms}}{\sqrt{3}}$$

Where, Vpu = measured voltage in pu

Vrms = phase to ground rms voltage in volt

Vm = Maximum line to line voltage

For maximum current calculation below formula is used.

  

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$$I_{base} = \frac{Base\ MVA}{Base\ Voltage}$$

$$I_{rms} = I_{pu} \times I_{base}$$

$$I_m = \frac{\sqrt{2} \times I_{rms}}{\sqrt{3}}$$

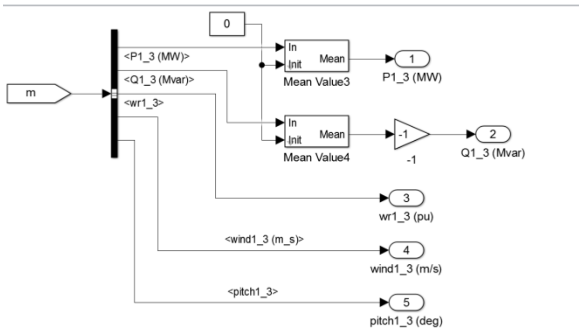
True Power can be calculated using below formula :

$$S_{kva} = V_{rms} \times I_{rms}^{*}$$

Now, Active power P = Real(Skva)

Reactive power Q = -Img(Skva)

**WIND FARM DATA ACUQISITION**




**Wind Farm data acquisition**

Here data is taken from the output of data acquisition of wind farm. The Bus Selector block outputs a specified subset of the elements of the bus at its input.

The block can output the specified elements as separate signals or as a new bus. The bus selector accepts a bus as input which can be created from the bus creator, bus selector or a block that define its output using bus objects. P1_3 (MW), Q1_3 (Mvar), wr1_3 ,wind1_3 (m/s) , pitch1_3 this parameters are measured from the bus selectors in this system. Active and reactive power of three wind turbine generators is measured using mean value block. the average of active and reactive power is taken. Reactive power is taken minus so that gain block is used and the value given to the block is (-1). All the value of all the parameters is given output by using out port.

Now the data is taken from the STATCOM acquisition. maximum voltage in pu and generated reactive power in MVAR is taken. scope is given the graph of it.

Now the derivative of active and reactive power

is taken by using derivative block. The active and reactive power is taken from the B25 bus. The derivative of both active and reactive power is given to the rate of power and respectively Goto blocks.

**BI BUS**: -

The voltage and current are taken from the from the BI 120Kv bus. Now the voltage is calculated by using gain block and given the value :-

The current is measured by using the math function because for power calculation the current is needed in conjugate form. the voltage cannot be measured in conjugate form because it is difficult to measured power, so for easy calculation and measurement, the current is taken in conjugate form.

Now multiplication of voltage and current conjugate gives Real power. Real part of true power is Active power and negative of imaginary part of true power is Reactive power.

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**ISLANDING TRIP SIGNAL :**

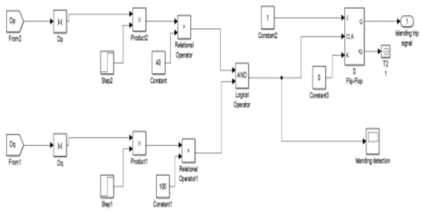

fig. Islanding detection methodology

Waveform for wind turbines and wind farm is as below and they are same for balanced or unbalanced condition.

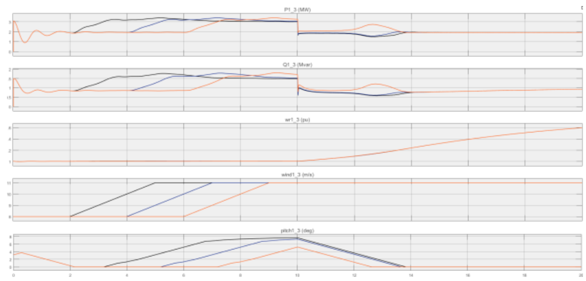

Fig. Wind turbines B575 waveform

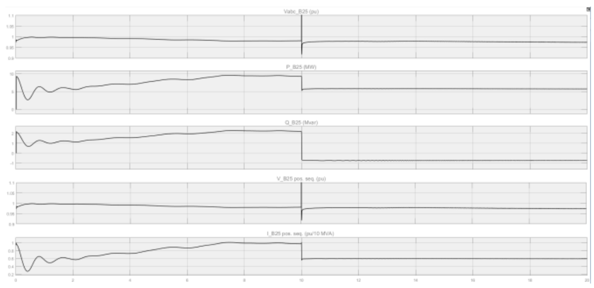

Fig. Wind farm Output waveform

**Change of active and reactive power for local load 6 MVA and islanding trip signal are as shown below**

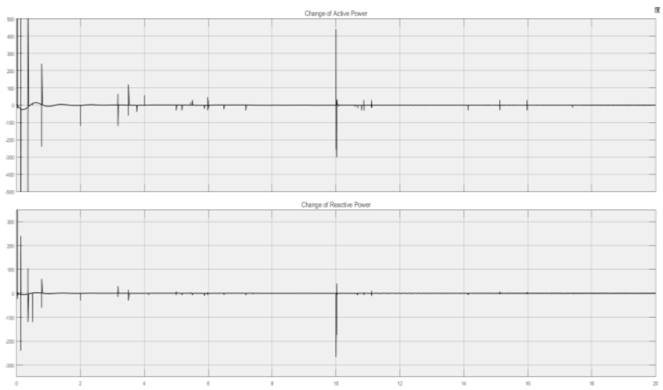

Fig. Change of output pow ers of DG for 6MVA lo

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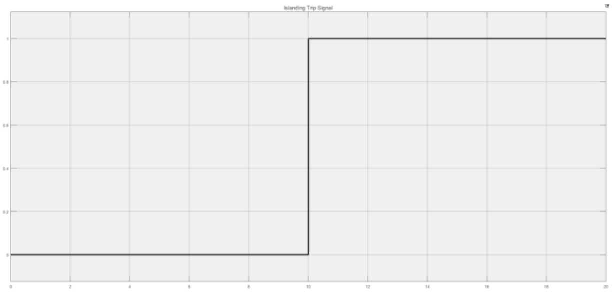

Fig. Islanding trip signal for 6MVA load

Change of active and reactive power for local load 12 MVA and islanding trip signal are as shown below :

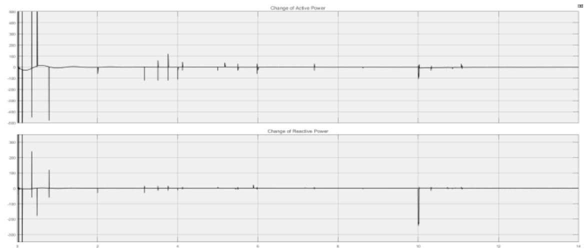

Fig Change of output powers of DG for 12MVA load

Fig. Islanding trip signal for 12MVA load

## VII. CONCLUSION

- As we have seen, Islanding detection can be done using many methods. Based on combined change of active and reactive power of DG is a passive system and can detect islanding in every situation whether system is in balanced condition or unbalanced condition.
- False detection is not problem using this method cause it is very efficient method and avoids false detection so this system is well suitable for islanding detection of DG with or without inverter.

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