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Integrated Passive Anti-Islanding Protection in Micro Grid

Abstract: - In last two decades due to major interest amongst power system engineers and policy makers penetration of different distributed energy resources (DREs) into power distribution network are significantly increased. Integration of DREs with conventional power grid is a complex issue and will impose some challenges against power engineers. The major challenge is protection of micro grid, which is based on how your protection strategies distinguish islanding and non islanding conditions correctly and timely. Methods used for have strengths and limitations in the areas like speed, accuracy, power quality and Non detection islanding zone. The prime motive of this research is to presents an efficient new integrated anti-islanding protection strategy using passive parameters. The proposed algorithm having a novel islanding detection technique, which discriminate the islanding events from the non islanding events of similar signature accurately with minimum non detection zone and minimum impact on power quality. The proposed strategy is the combination of different conventional and latest passive relays based on single and multiple parameters. Integration of different relays made in such a strategic way that it combines the strengths and benefits of each method and minimizes their limitations. The presented algorithm tested under MATLAB/SIMULINK environment in different network conditions. Finally, the efficiency of the algorithm has checked by testing it on standard microgrid structure. The results received from simulation confirmed that algorithm is detecting islanding conditions reliably and efficiently, followed by generation of trip/block signal correctly.

Keywords: *Anti-islanding protection, Distributed generation, Micro grid, Non-detection zone, Rate of Change of frequency (ROCOF)*

I. INTRODUCTION

Modern power system is very complex and highly sensitive network. One of the key factors responsible for it is high integration of different distributed energy resources (DERs) with the grid. Increasing penetration of DERs into main grid has already raised many issues. Protection, fast and correct detection and quality of power are major problems which were emerged with integration of DERs. During the islanded mode a portion of a network is separated from main network and continues to supply power from one or more distributed generator. Islanding can be either intentional or unintentional. Intentional islanding arises during system disturbances like fault condition. An unintentional islanding arises when system fails to detect islanding which leads to form a micro grid. [1,2].

It also involves some protection issues like personal safety, hazard, and out-of-phase auto reclosing. The time taken for detection in case of islanding events is a crucial issue as it should be discriminated before reclosing operation. [3] According to the IEEE standard 1547-2003 islanding event should be identified within 2 seconds. [4] As per some grid codes after the islanding the islanded network should have sufficient generating capability to operate independently in islanded mode [5]. This makes islanding detection very important event for protection purpose as it not only disconnects DGs but also prepare the islanded network in a new control mode.

Large number of methods presented by several researchers in recent years. All methods are involved measurement of different electrical parameters of the system at common coupling point with main grid. All islanding detection techniques are classified into two groups called local and remote methods. As the name suggests in remote methods the islanding detection is performed using communication link. Phasor Measurement Unit based measurement [6-7] is required and power line signals [8-9] are utilized to detect islanding and delivering trip signals to circuit breaker. Remote methods are very fast, discriminating islanding from disturbances and having negligible NDZ. However, drawbacks like high costing due to extra communication

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setup, complexity, and requirement of backup protection due to vulnerability of failure of communication channels are issues which make it unpopular [6-9].

Local methods are further sub-divided into active and passive methods. Active methods are, type of DGs dependent method. To check system islanding detection capabilities a deliberate disturbance is injected into the network in the active method. Some of the methods which are used for inverter based DERs are change in output power detection method [10], change in impedance method [11-12], current harmonic injection [13], voltage/frequency drift [14-15], sandia voltage/frequency shift [16] and positive feedback method [17]. Some islanding detection techniques used for synchronous based DGs are positive feedback power control [18-20]. Literature review of all these active methods urged that these methods are faster in islanding detection and have low NDZ in comparison to passive methods but it suffers with degradation of power quality due to introduction of perturbation in the system.

Passive methods involve monitoring variations of electrical parameters like Voltage, Frequency, and active-reactive power at PCC. Islanding is detected when single or multiple quantities crosses the limit set by preset thresholds. Under/Over Voltage (UOV) and Under/Over Frequency (UOF) are single parameter-based relays, which are the most standard methods utilized for detection. Another method which utilizes a single parameter for islanding detection are Rate Of Change Of Frequency (ROCOF) [21], Vector surge relay [22], Rate Of Change Of Voltage (ROCOV) and Rate Of Change Of Reactive Power (ROCORP) [23], Rate Of Change Of Phase Angle Difference (ROCOPAD) [24]. Some methods which uses two parameters for islanding detection. These include Rate of Change of Frequency over Voltage (ROCOF/ROCOV), rate of change of frequency with respect to active power (df/dp) [25-26]. These are efficient during high power mismatch condition but they face problems in detecting islanding during high reactive power imbalance condition. ROCOPAD suffer from major disadvantage of false tripping during certain non-islanding event like short circuit fault condition.

To overcome limitations of above schemes researchers and power engineers suggested some intelligent/advanced methods using signal processing. Some of the methods are Wavelet Transform (WT), Artificial Neural Network (ANN), Fuzzy Logic (FL) and Support Vector Machines (SVM) [27-33]. Though the Artificial Intelligence (AI) based islanding detection schemes provide encouraging results, requirement of many input patterns, complicated training procedure and unsatisfactory results in case of unknown data sets are the several limitations of the above schemes. To conquer the constraints of active and passive methods and combine advantages of both, hybrid techniques are used. In hybrid method a signal is added into a system. It has advantages as active methods but is difficult to apply and degrades power quality.

The detailed literature reveals that there is no perfect islanding detection technique available. Every method has one or more limitations. Therefore, to resolve the above-mentioned issues, a new integrated anti islanding protection technique using combination of most sensitive parameters is presented in this paper. The proposed anti islanding strategy is tested on standard microgrid with different network conditions. The outcome indicates that the suggested anti islanding technique is efficient, fast, and reliable.

The paper constitutes parameter selection based on it’s sensitivity and performance issues with anti-islanding protection in section II. Design considerations of proposed algorithm are presented in section III. Testing of suggested technique is exhibited in section IV. Section V, VI and VII deals with result analysis, discussion, and conclusion.

II. SENSITIVITY ANALYSIS AND PERFORMANCE ISSUES

2.1. Sensitivity Analysis and Parameter Selection:

The conventional methods discriminate the islanding and non-islanding conditions based on performance of single passive parameter like voltage, frequency, or power. While some advanced and hybrid methods utilize combination of more than one parameters to detect islanding. The selection of passive parameter for islanding detection for anti islanding protection is very important criteria. The sensitivity of any passive parameter determines the accuracy and reliability of anti islanding protection. To find the most sensitive passive parameters for consideration, sensitivity analysis of different single parameters and combination of two parameters is necessary. Performance analysis of total 16 single and combinations of two passive parameters are done under different islanding and non islanding conditions under different power imbalance scenario.

Overall performance of these parameters is obtained by calculation of average percentage of performances as shown in Fig. 1. Based on this analysis the top five sensitive parameters are considered for further analysis:

- Rate Of Change Of Frequency Over Reactive Power (ROCOFOQ): df/dq.
- Rate Of Change Of Frequency Over Exciter Voltage (ROCOFOV): df/dv
- Rate Of Change Of Active Power (ROCOP: dp/dt
- Rate Of Change Of Voltage (ROCOV): dv/dt
- Rate Of Change Of Frequency (ROCOF): df/dt.

The Under/Over frequency relays are the conventional relays which are normally used for anti islanding protections. A detailed analysis has been done and the average percentage of performance is found as per Fig.2

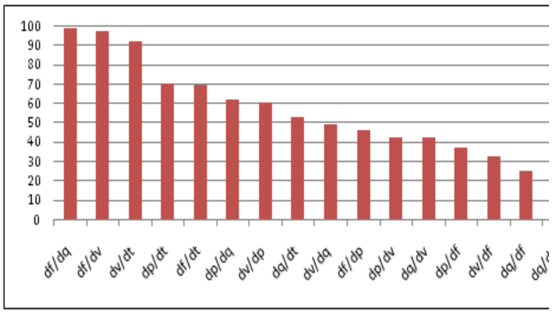

Figure 1. Performance analysis of Passive parameters

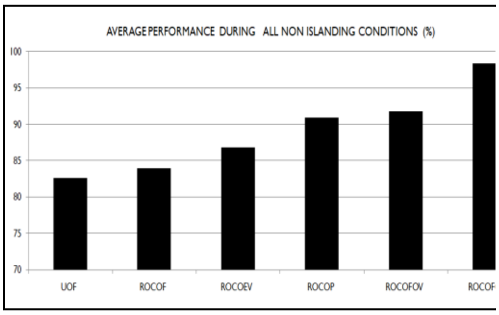

Figure 2. Comparative analysis of selected passive parameters

Following are the findings of performance analysis of relays based on selected parameters.

2.1.1 UOF Relay:

When islanding mode happens during power mismatch between load and generation, generator's speed changes according to swing equation, as frequency depends on speed, frequency also changes. When G>L, frequency will increase and it will decrease for G<L. hence islanding can be detected using OUF relay.

Advantages:

- The advantage of this method is that it does not affect the power quality and the cost is low.

Issues:

- The disadvantages are that it is difficult to predict the detection time and it has a relatively large NDZ
- Under low power mismatch conditions, there are minute variations in the frequency which increase detection time.
- Under short circuit fault due to sudden decrease in large frequency variations may cause mal operations of relay.

2.1.2 ROCOF

Advantages:

- ROCOF is faster than OUF relay, so for same required operation time NDZ for ROCOF is reduced.

Issues:

- For low (Less than 15%) power imbalance, frequency reduces slowly so islanding is tough to identify using ROCOF.
- To reduce NDZ threshold setting must be reduced which may cause mal-operation of relay in non islanding events.
- Under network transient conditions it may maloperate due to high frequency variations.
- Under short circuit fault due to sudden decrease in load, large frequency variations may cause mal operations of relay

2.1.3 ROCOV

With DGs working at or near unity power factor, capacitor bank in network is the only source of reactive power throughout islanding. Islanding will cause change in reactive power which in turn change the system voltage hence ROCOV relay detects islanding conditions.

Advantage:

- During short circuit fault, the system voltage drops suddenly while under islanding mode voltage drops slowly. ROCOV can easily discriminate islanding and fault.

Issue:

- When low power factor load is disconnected from the network, reactive power imbalance increases, which will cause change in voltage and ROCOEV may mal-operate.

2.1.4 ROCOP

Advantages:

- Fast response: This can be crucial for preventing safety hazards and equipment damage.
- Sensitivity: sensitive to even small changes making it comfortable during low power imbalances.
- Simplicity: requiring only measurements of active power and its rate of change.
- Cost-effective: does not require additional hardware.

Issue:

- Sudden load changes or switching events can cause ROCOP to trigger false alarms.

2.1.5 ROCOFOV

Advantages:

- Quicker islanding detection.
- Lower cost and easy implementation

2.1.6 ROCOFOQ

Advantages:

- ROCOFOQ can be sensitive to small power imbalances that might not trigger ROCOF or ROCOV

2.2 Performance issues with Anti-islanding Protection:

In this section we discussed the different performance issues which make anti-islanding protection more challenging for power engineers.

2.2.1 Threshold Setting:

In frequency based (OUF) relays islanding event can be detected if the frequency is not in the pre-specified range known as threshold. Following are major issues for frequency relays, which made threshold setting very challenging.

- Threshold setting depends on Mode of Operation (Grid connected or Islanded). As per IEEE standards allowable frequency variations (Threshold) are different under GRID connected mode and Islanded mode shown in Table 1. Also, DG must not be disconnected for small frequency variations, if relay is set to meet this requirement it may not detect islanding condition within time.

Table 1 Frequency variations as per IEEE 1547 standard

Method	**Threshold as per IEEE 1547**			
	Grid connected mode		**Islanded mode**	
OF relay	+2.5% (+1.5Hz for 60 Hz system)	61.5Hz	+5% (+3 Hz for 60 Hz system)	63Hz
UF relay	-2.5% (-1.5Hz for 60 Hz system)	58.5Hz	-5% (-3 Hz for 60 Hz system)	57Hz
ROCOF	Varies from 0.1 to 1.5 Hz/sec			

- If relay is made more sensitive by setting to detect all islanding conditions it may maloperate for small frequency variations occurred during other non islanding conditions
- As shown in Fig 3 and Fig.4, from the simulation results obtained, the frequency variations and ROCOF also depend on power mismatch during islanding conditions. So, the detection time of frequency-based relay is largely depending on Threshold setting. It will be tough to make balance between detection of islanding within time limit without mal operation.

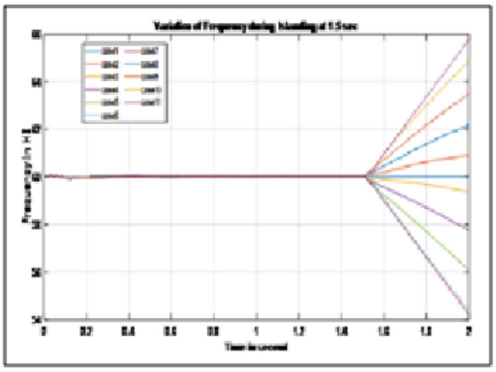

Figure 3. Frequency variations during islanding conditions under different power mismatch

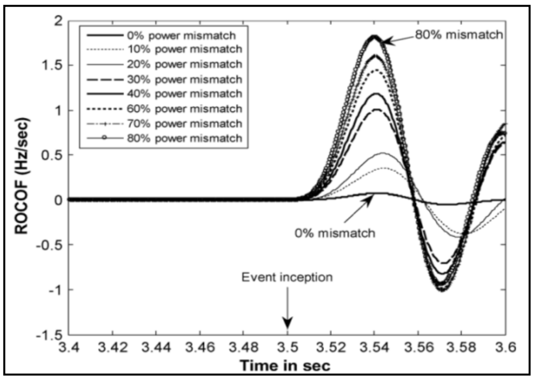

Figure 4. Variation of ROCOF

2.2.2 Critical Power Imbalance:

The islanding detection capability of frequency-based relay is known from its performance curve, having relation between active power imbalances and islanding detection time. A critical power imbalance is defined as a minimum active power imbalance that the relay can detect with limit in operation time imposed by IEEE standards with considering the auto-reclose. IEEE standards impose a limit of 500ms for Anti islanding relay to disconnect the DREs by issuing trip signal considering Auto re-closer operation. As shown in Fig.5 of performance curve following points are derived

- If time barrier of 500 ms is considered then critical power imbalance will be 19%.
- Frequency-based relays unable to detect islanding incase of active power imbalance 19% and below.
- If we want to improve system stability we have to reduce critical power imbalance.
- Reduction in critical power imbalance will increase detection time drastically which will violate the limit of 500ms.

So finally, it is extremely challenging to create balance between critical power imbalance and detection time.

2.2.3 Non-Detection Zone (NDZ)

Power mismatches lower than the critical power imbalance determine a non-detection zone. As per Fig.5 frequency-based relay have 15% to 20% non detection zone. If we want to reduce the NDZ, detection time will be increased. As we reduce the detection time the critical power imbalance and NDZ will also increase which affect the system stability.

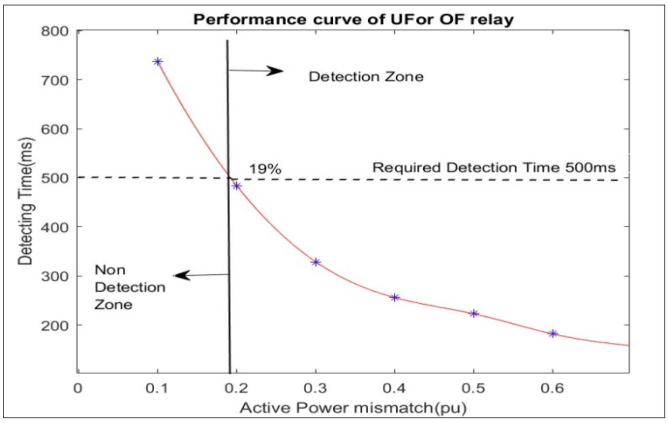

Figure 5. Performance curve

2.2.4 Effect of Inertia Constant (H):

As the value of machine inertia constant H increases, frequency deviations will be smaller and it will increase the detection time as well as non detection zone.

2.2.5 Susceptibility of Frequency Based Relay:

Frequency oscillations are large enough during non islanding conditions like fault, Capacitor switching and serious overload conditions, which may cause mal-operation of UOF and ROCOF relays.

III. PROPOSED ALGORITHM FOR ANTI ISLANDING PROTECTION

3.1 Design consideration of proposed algorithm:

- The main technical parameters to assess its suitability are: size of NDZ, Reliability and effect on the system and Operation time. Our suggested method is devised with a logical combination of different passive methods to eliminate following issue and enhance their performance.
- The main challenge when designing a modified technique is to choose the most significant parameter and its threshold value to detect islanding while avoiding nuisance tripping. The performance analysis of different passive parameters shows that frequency, voltage, active power, and reactive power are most sensitive parameters during different conditions, Hence, the proposed algorithm includes these parameters. Threshold settings for frequency-based relays are done based on combination of desired sensitivity and grid characteristics and its regulatory requirement.
- Passive Islanding detection technique is utilized due to its cost effectiveness and good power quality. The under/over frequency relay and ROCOF relay are simple to implement, so these relays are integrated without addition of any cost.

- OUF and ROCOF relay operates faster in high power imbalance condition so to avail advantage of fast tripping their trip signals are combined with **logical OR gate 1.**

- Islanding detection capability of the voltage-based relays will be more than the frequency-based relays when the Synchronous DG system operates with small active power imbalance, independent of the load type.

- In the islanding condition, voltage relays may operate with shorter delay than the frequency relays if an adequate reactive power imbalance exists in the islanded system, because the voltage change is independent of the mechanical inertia.

- On the other hand, when Synchronous based DGs operate at unity power factor, a considerable deficit of reactive power. When islanding occurs a voltage relay has larger NDZ than a frequency-based relay. So, a voltage relay can be combined with a frequency-based relay as a complementary device for anti-islanding protection.

- As mentioned earlier frequency-based relay may mal-operate during short circuit conditions. In short circuit fault voltage drops suddenly while in case of Islanding situation voltage drops slowly. The ROCOV relay which measures change in voltage can separate Islanding condition from short circuit fault and avoid nuisance tripping. To increase the efficiency of the anti-islanding protection scheme, the frequency and voltage-based relays can be combined. Hence in proposed algorithm trip signal of frequency-based relay is connected with ROCOV relay using logical AND gate 1.

- During load variation with low power factor and during capacitor switching reactive power in the network increases which may cause mal operation of ROCOV relay but there want be detectable change in active power hence ROCOP relay not operates. Hence to avoid false tripping of ROCOV relay its trip signal is connected with output of ROCOP relay using AND gate 2.

- Sudden load changes or switching events can cause ROCOP to trigger false alarms, requiring additional filtering or confirmation mechanisms. Combining ROCOP with other methods, such as ROCOV and ROCOF, can improve overall detection accuracy and reliability. It is also one of the reasons to connect ROCOV and ROCOP using AND gate 2.

- From the simulation studies and sensitivity analysis carried out for single DG and multi-DG system configuration, in different islanding and non-islanding conditions during different power mismatch scenario, it is observed that by combining two passive parameters as Islanding detection indices there is improvement in overall performance of detection method. From the sensitivity ranking carried out the most sensitive first two combinations are included in proposed algorithm to enhance the performance.
- ROCOFOV is having fast detection time in comparison to ROCOFOQ, while accuracy of ROCOFOQ is more than ROCOFOV. Hence trip signal of AND gate 2 is combined with ROCOFOV using logical OR gate 2.
- To enhance reliability trip signal of logical OR gate 2 is connected with ROCOFOQ relay using logical OR gate 3 which gives trip signal with some time delay when all previous methods fail to give correct tripping.

3.2 Proposed algorithm:

Fig. 6 shows the proposed anti islanding protection scheme based on logical combination of different relays to achieve.

IV. TEST SYSTEM

The multi DGs microgrid system is studied shown in Fig. 7. It comprises of a microgrid system with 4 DG units (3 wind farms and 1 emergency diesel generator), The DG units are placed at a bus number 4,5,7 and 8 nominal voltage is 690V. The specifications of generator, DGs, transformers, distribution lines, and load are mentioned in Table 2.

The different signals like current, voltage and power are measured during different conditions or system disturbances. The simulation done at 1.0 kHz (20 samples per cycle on 60 Hz base frequency). The complete simulation is carried out using MATLAB (SIMULINK) package fig. 8. The effectiveness of the suggested technique is verified under various islanding and non-islanding conditions, under different power mismatch conditions, like load increment/decrement, capacitor switching, different inertia constant and different fault conditions. The excellence of the suggested method is presented in result analysis section by comparing it with other methods used.

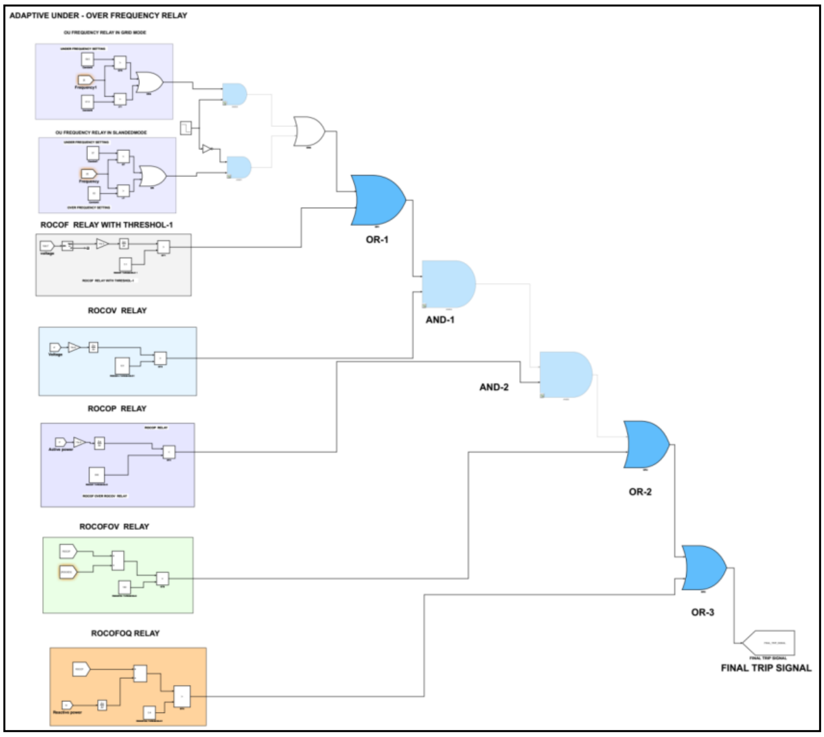

Figure 6. Proposed Algorithm

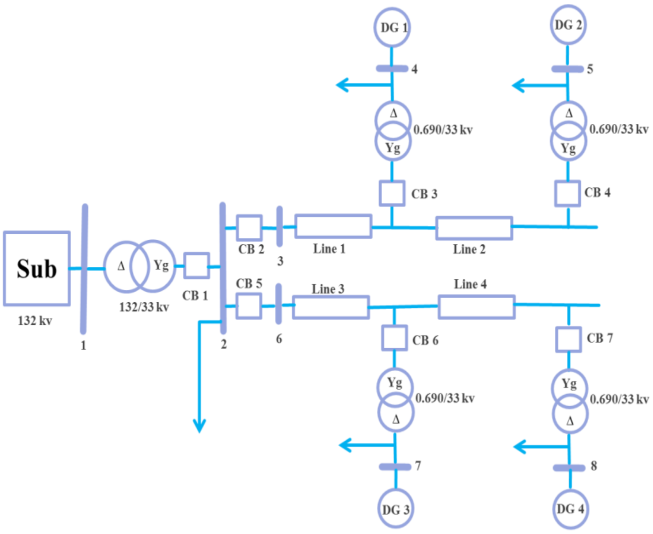

Figure 7. Microgrid with multiple DG interface under consideration

Table 2 System Data

Thevenin Equivalent (Sub) Data		**Line data**		
Nominal Voltage (kv)	132		Line 2-3	Line 3-4
Shirt Circuit Power (MVA)	1500	Resistance (ohm/km)	0..37	0.97
Resistance	0	XL (ohm/km)	1.57	4.18
Inductance (mH)	30.80	Length (km)	1	0.5

Synchronous Generator Data		**Transformer Data**		
Pairs of Pole	2		TR:1 132 kv / 33 kv	TR:2 33 /0.690 kv
Nominal Power (MVA)	30	Nominal Power (MVA)	100	50
Nominal Voltage (v)	690	Primary Winding	Delta	Delta
Inertia Constant	1.5	Primary Voltage (kv)	132	33

Xd (pu)	1.400	Secondary Winding	Star Ground	Star Ground
X’d (pu)	0.231	Secondary Voltage (kv)	33	0.690
X”d (pu)	0.118	Resistance (pu)	0	0
Xq (pu)	1.372	Inductance (pu)	0.04	0.04
X’q (pu)	0.800	**Exciter System Data**		
X”q (pu)	0.118	Tf (s)	0.005	
T’do (pu)	5.500	Ka	270	
T”do (pu)	0.050	Ta (s)	0.1	
T’qo (pu)	1.250	Ke	1	
T”qo (pu)	0.190	Te (s)	0.65	
Stator Resistance (pu)	0.0014	Kf	0.048	
Leakage Reactance (pu)	0.050	Tf (s)	0.95	
		Vrmax (pu)	7	
		Vrmin (pu)	-4	

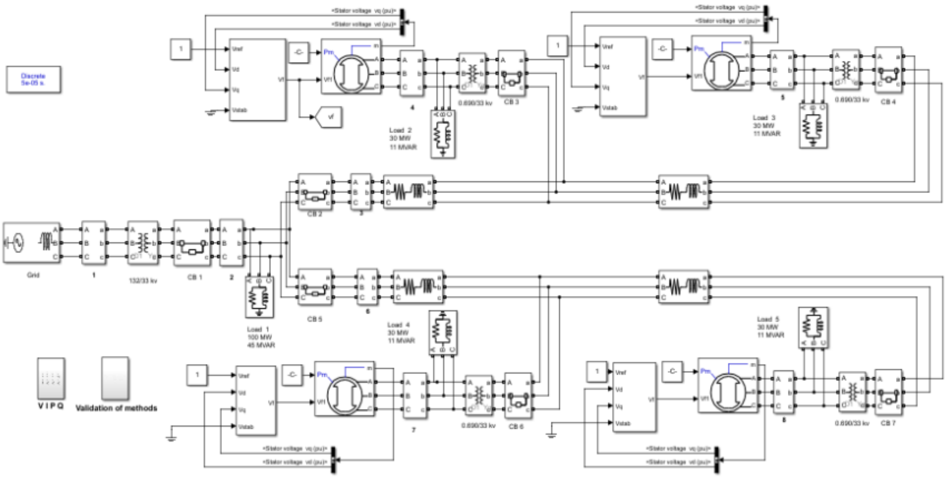

Figure 8. MATLAB/SIMULINK model of test system.

V. RESULT ANALYSIS

The attainment of the suggested method is reviewed and compared with existing single and two parameter methods under different network conditions.

5.1 Case 1: Operation under higher power mismatch condition:

When islanding mode happens with high power mismatch, the frequency and voltage change significantly. As a result, the ROCOF, ROCOV and OF/UF relays detect islanding mode, and the output of their AND gate 1 becomes one. The active power variation starts to increase in islanding network and the ROCOP relay send signal 1. Finally, the outcome of the AND gate 2 becomes one. In this case the ROCOFOV and ROCOFOQ relays will detect islanding mode with a time delay. Finally, the outcome of OR gate 3 becomes one and final trip signal will be issued by detecting islanding. The trip signals during simulation are as per Fig 9.

5.2 Case 2: Operation under Low power mismatch condition:

When islanding mode happens with low power mismatch, ROCOF, ROCOV, and OF/UF relays may not detect islanding mode. As a result, the output of AND gate 1 becomes zero. In low power mismatch as variation in active power is very low, ROCOP relay fails to detect islanding, hence output of AND GATE 2 is also zero. ROCOFOV is faster and accurate upto 10% power mismatch condition. Hence output of OR 2 GATE becomes one and consequently output of OR GATE 3 becomes one. Hence islanding is detected by ROCOFOV upto

10% power mismatch condition. Under 0% power mismatch condition even ROCOFOV fails to detect islanding condition as shown in Fig. 10. Hence output of OR GATE 2 becomes zero. In this condition ROCOFOQ being most accurate detects islanding with time delay as shown in Fig. 11., which make output of OR GATE 3 one and final trip signal will be issued by detecting islanding condition. As shown in Fig. 12, when all detection techniques fail during zero power mismatch condition, the proposed method detects it correctly.

5.3 Case 3: Operation under different fault (non-islanding) condition:

When Double Line to Ground (L-L-L-G) fault occurs at 1.0 sec with 70% loaded line, as shown in Fig. 13-14 the OU/UF and ROCOF relays mal-operate and but they are controlled by the ROCOV relay by making output of AND gate 1 is zero. Hence output of AND gate 2 will be zero even if ROCOP relay mal-operates. ROCOFOV and ROCOFOQ relays have higher accuracy so they avoid mal-functioning durig short circuit faults. Ultimately, the final trip signal becomes zero, and the suggested algorithm does not generate any trip signal during faults conditions as shown in Fig. 15.

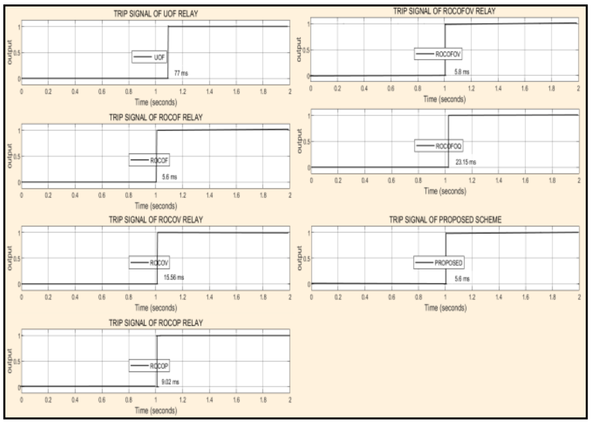

Figure 9. Trip signal during 80% power mismatch condition

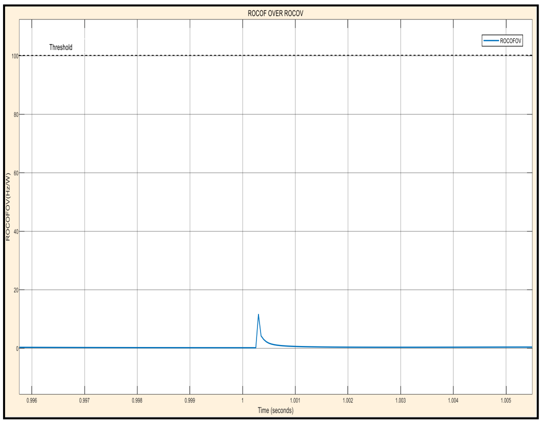

Figure 10. ROCOF over ROCOV during 0% power mismatch

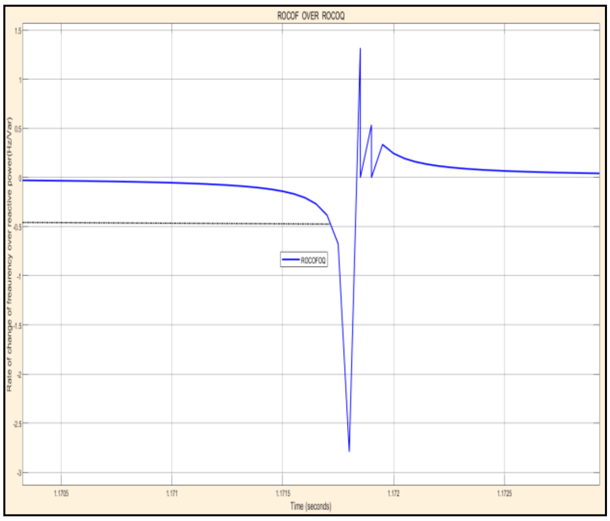

Figure 11. ROCOF over ROCOQ during 0% power mismatch condition

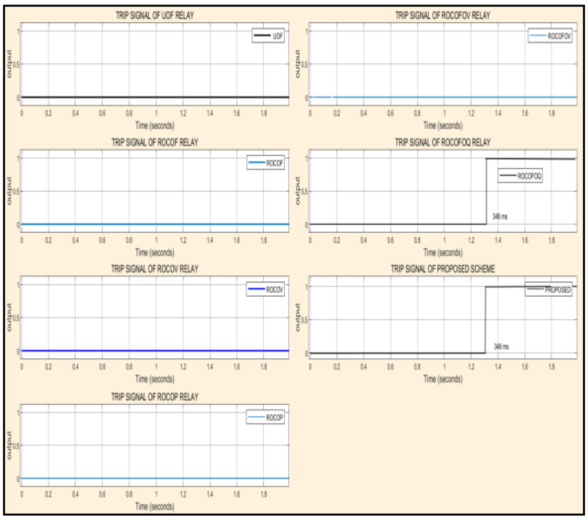

Figure 12. Trip signal during 0% power mismatch condition

5.4 Case 4: Operation under load variations (Non islanding) condition:

During load variation in a system working on higher power factor OUF, ROCOF and ROCOP relays mal-operated. So, output of OR gate 1 is one. The mal-operation of OUF, ROCOF relay is blocked by non-operation of ROCOV relay. So, output of AND gate 1 is zero. The mal- operation of ROCOP relay is also block by zero signal from AND gate 1. So, output of AND gate 2 is zero. As ROCOFOV and ROCOFOQ are very accurate, they do not operate during load variations. So final trip signal will be zero as shown in Fig. 16. Load variations having low power factor cause large variations in reactive power. Low power factor Voltage variation may initiate mal operation of ROCOV relay. Mal-operation of ROCOF and ROCOV relay will be blocked by ROCOP relay by making output of AND gate 2 zero. As ROCOFOEV and ROCOFOQ are very accurate hence they do not operate during load variations. So final trip signal will be zero as shown in Fig.17.

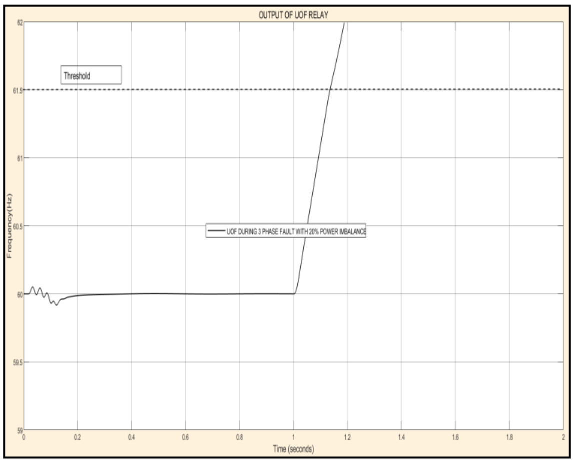

Figure 13. UOF relay Maloperation during L-L-L-G Fault at 1 sec with 70% power mismatch

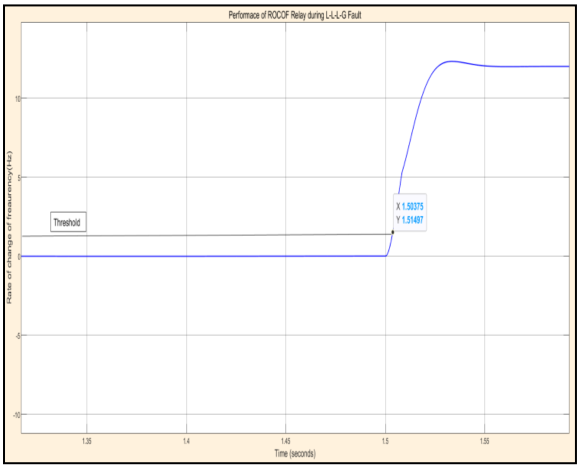

Figure 14. ROCOF relay maloperation during L-L-L-G Fault at 1 sec with 70% power mismatch

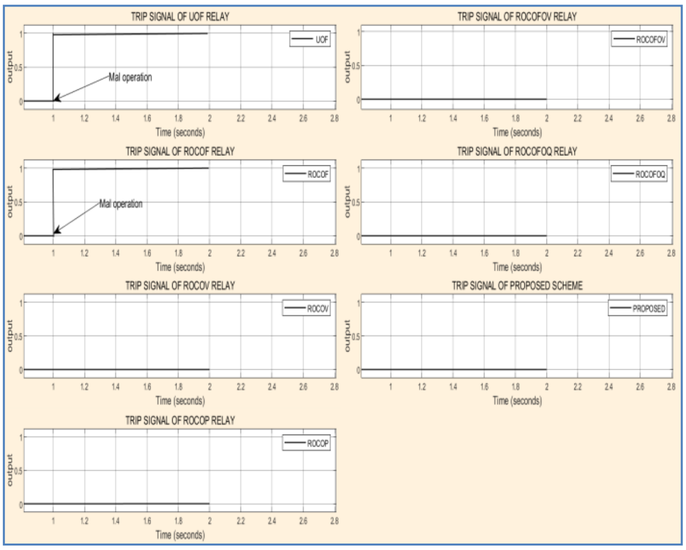

Figure 15. Trip signal during L-L-L-G Fault at 1 sec with 70% power mismatch

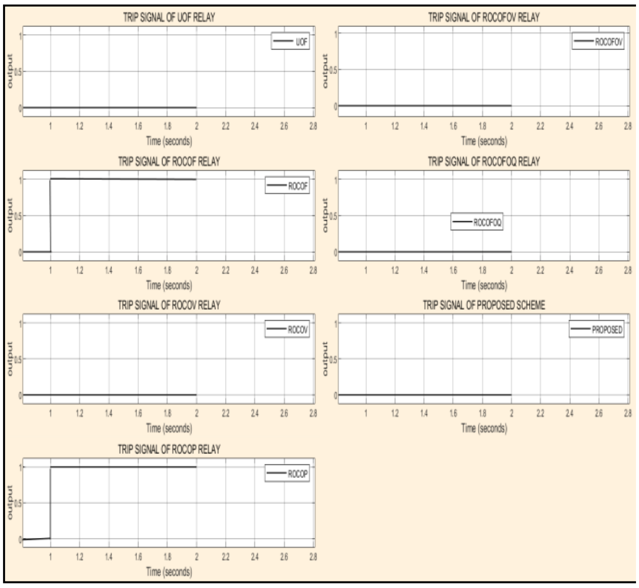

Figure 16. Heavy Load removed at (70% Power imbalance) system having high pf

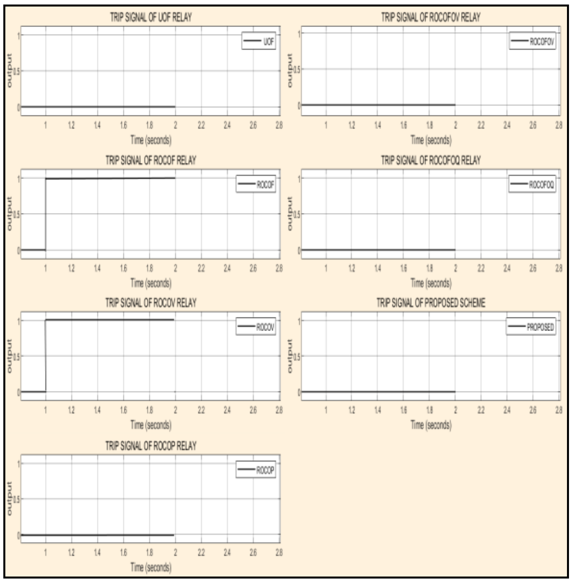

Figure 17. Heavy load removed at (70% Power imbalance) system having low pf

5.5 Case 5: Operation under capacitor switching:

During capacitor switching reactive power imbalance may arise with higher magnitude, hence the system voltage and frequency changes and ROCOF and ROCOV relay may mal operate as Fig.18. The mal-operation of ROCOF and ROCOV will be blocked by non-operation of ROCOP relay, so output of AND gate 2 will be zero. So final trip signal will be zero.

5.6 Case 6: Operation under addition/removal of DG:

Large variations occur in system frequency and power during the sudden removal or addition of DG in the system. This make the ROCOF and ROCOP relays to maloperate and send tripping signal. The proposed algorithm blocks these tripping signals with ROCOV relay as shown in Fig. 19.

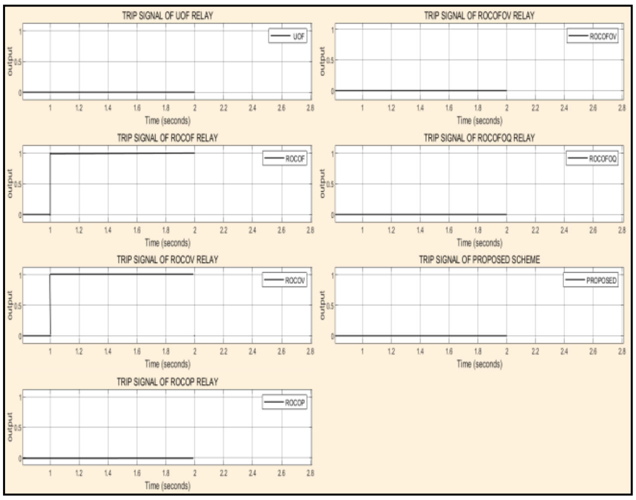

Figure 18. Capacitor connections at 1sec system having 50% Power imbalance

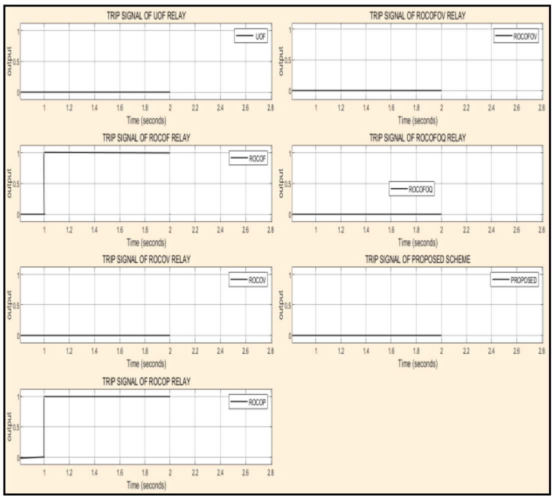

Figure 19. Tripping signal after removal of DG by opening CB - 6 at 1.0 sec

VI. DISCUSSION

Detailed investigate the suggested algorithm in different system conditions shows following results

- To avoid system instability and equipment damage caused by high power imbalance a quick operation of anti islanding protection is necessary. The logical combinations of OF/UF, ROCOF , ROCOP and ROCOV relays as per suggested algorithm provided the fast and reliable operation.
- Frequency and voltage fluctuates faintly during islanded mode having low power imbalance. Generator becomes unstable after long time which allow more time to detect it. Where conventional relays failed to detect it ROCOFOV and ROCOFOQ relays of proposed algorithm successfully detect it with some time delay
- Frequency based relays (UOF/ROCOF) are more susceptible for maloperation during short circuit fault.ROCOV relay constrain the frequency relays and the suggested algorithm operates by not generating trip signals and identifying it as non islanding case properly.
- During load variations, the system works under different power factor conditions and mal-operations of conventional relays are blocked by suggested algorithm.. The suggested algorithm not generating trip signal and identifying it as non-islanding case properly.
- During capacitor switching condition mal operation of ROCOF and ROCOV relay is blocked by ROCOP relay. The suggested method not generates any trip signal and identifying it as non islanding case correctly.
- Table 3 clearly shows that proposed anti islanding protection scheme is highly efficient as

Table 3. Performance analysis

Case	**Power mismatch cases**	**Condition**	**No of cases**	**Total cases**	**UOF**	**ROCOF**	**ROCOV**	**ROCOP**	**ROCOFOV**	**ROCOFOQ**	**PROPOSED**
					No. of cases detected correctly						
1	20	Load Increment	8	160	134	129	138	146	149	156	158
	20	Load Decrement	8	160	131	135	135	140	143	157	159
2	20	Capacitor connection	1	20	17	17	18	18	20	20	20
	20	Capacitor disconnection	1	20	18	17	17	19	19	20	20
3	20	Fault conditions	5	100	83	88	91	95	94	99	100
TOTAL				480	381	388	399	418	425	452	457
OVERALL PERFORMACE (%)					82.60	83.91	86.73	90.86	91.73	98.26	99.35

compared to other methods. Fig. 20 shows the operational curve indicating detection time Vs allowable critical power imbalance of suggested method.

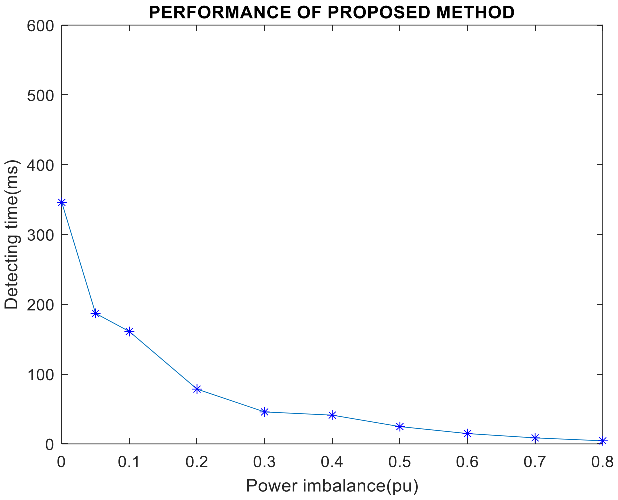

Figure 20. The performance curve of proposed method

VII.CONCLUSION

An integrated anti-islanding protection scheme is suggested which enhance the detection time and eliminate NDZ and avoid unnecessary mal-operation of classic relays under different non islanding conditions. The key contributions of proposed anti-islanding protection are sum up as follows:

- The suggested anti-islanding protection scheme improves detection time significantly with minimum NDZ.
- The suggested anti-islanding protection scheme prevents mal-operation during all type of system disturbances..
- As suggested anti islanding protection comprises basic relays, which makes it simple and practically easy to implement.
- The proposed scheme can be applied to single as well as multi DG system integrated all type of DREs.
- The proposed scheme having minimal effect on power quality.

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