RESEARCH ARTICLE OPEN ACCESS

A Comparative Study of Fault Analysis for Transmission and Generation Systems

[1]Sarnab Ghosh, [2]Atul Soni, [3]Kritika Verma, [4]Shashikant Basniwal, [5]Shivam Sharma
[13]B.tech student, Department of Electrical Engineering, Arya College of Engineering and Technology, Jaipur
[2]Assistant Professor, Department of Electrical Engineering, Arya Institute of Engineering and Technology, Jaipur
[45]B.tech student, Department of Electrical Engineering, Arya Institute of Engineering and Technology, Jaipur

ABSTRACT

This paper shows that why fault analysis is needed in power systems. Power system means where the power is transmitted from the generating plant to the customer end through transmission lines. Current passing through transmission lines may leak out due to environmental disturbances, due to which power loss occurs in the system. To analyze the fault, the concept of symmetrical components is used. Fault analysis is used in microgrids and distributed generators. Fault resistance is a critical component of electric power systems operation due to itsstochastic nature. If not considered, this parameter may interfere in fault analysisstudies. The fault analysis of unbalanced three-phase distribution systems can be done by an iterative fault analysis algorithm considering a fault resistance estimate. Thisalgorithm is composed by two sub-routines, namely the fault resistance and the busimpedance. The fault resistance sub-routine, based on local fault records, estimates thefault resistance. The bus impedance sub-routine, based on the previously estimatedfault resistance, estimates the system voltages and currents

Keywords- Fault analysis, microgrid, Distributed generators

I.INTRODUCTION

It is the study of abnormal conditions such as symmetrical and unsymmetrical faults. It can be caused by insulation failure of equipment, flash-over of lines due to lightning stroke. Fault analysis is needed in order to design the protective relays, design circuit breakers. Generator is represented as constant voltage behind sub-transientreactance. Current carried by shunt elements of transmission lines are neglected. Fault analysis is done under no-load conditions such thatpre-fault voltage is maximum and fault current is high. Synchronousmotor acts as a generatorduring fault analysis. Induction Motor can be ignored during fault analysis. Variation in speed of alternator is neglected such that frequency remains constant.

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In this paper, we analyze about different types of faults using symmetrical components and how fault analysis can be used on distributed feeders with distributed generators and microgrids.

II.SYMMETRICAL COMPONENTS

In an unbalanced system, each equation involves other phases. Different magnitude or phase differences of phasor quantity(V, I) in a system. According to the Fortesque theorem, an unbalanced system of n-phasors can be resolved into an 'n-1' system of balanced phasor and a '1' co-phasor. An unbalanced quantity is the sum of positive sequence components, negative sequence components and zero sequence components

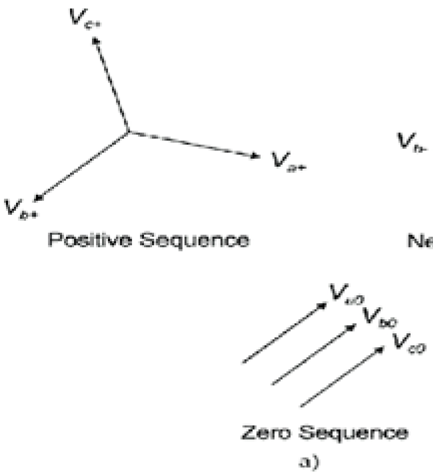


Fig.1. Components of unbalanced quantity

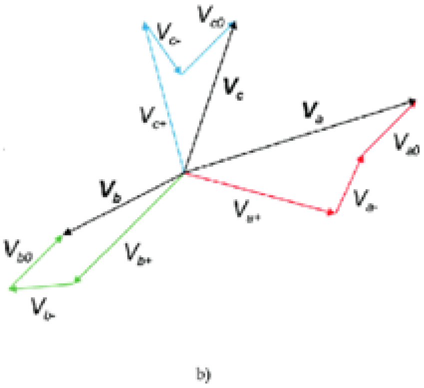


Fig.2.Vector representation of components

A. Positive Sequence

Same phase sequence as the original phasors.Displaced from each other by 120 degrees and are equal in magnitude.Only positive sequence components are present in a balanced 3-phase system.

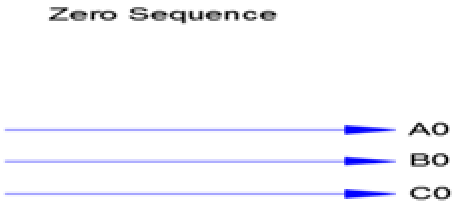


Fig.3.positive sequence

B. Negative Sequence

Opposite phase sequence as of original phasors, Equal in magnitudes and displaced from each other by 120 degrees.

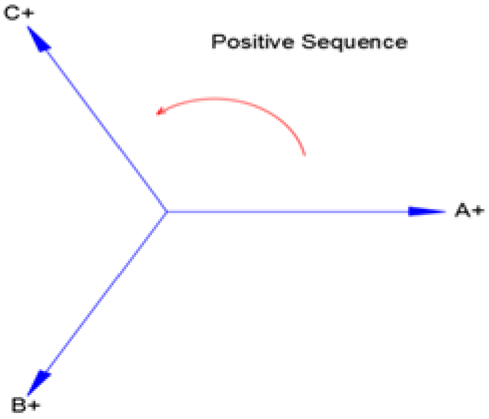


Fig.4. Negative Sequence

C. Zero Sequence

Equal in magnitude. Zero phase displacement from each other.

$$V_a=V_{a1}+V_{a2}+V_{a0}$$

$$V_b=V_{b1}+V_{b2}+V_{b0}$$

$$V_c=V_{c1}+V_{c2}+V_{c3}$$

DPhase components and Symmetrical Components

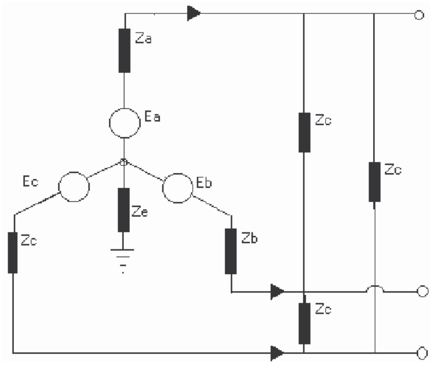
$$\begin{bmatrix} v_a \\ v_b \\ v_c \end{bmatrix} = \begin{bmatrix} 1 & 1 & 1 \\ 1 & \alpha^2 & \alpha \\ 1 & \alpha & \alpha^2 \end{bmatrix} \begin{bmatrix} v_{a_0} \\ v_{a_1} \\ v_{a_2} \end{bmatrix}$$

A operator which when operates upon a phasor, rotates it by +120 degree without changing the magnitude of phasor upon which it operates.

$$[V^{abc}]=[A][V^{012}]$$

III. SYMMETRICAL FAULT

A.Three Phase Fault



Perfectly balanced system. Induced EMF is always balanced and has positive sequence. Each phase has equal impedance .hence current also balanced.

$I_a=I_b=I_c=E/(Z_1+Z_f)$

Fault current:

E/(Z1+Z2)

Short circuit MVA:

$$S=3[V_{a0}I_{a0}^{*}+V_{a1}I_{a1}^{*}+ V_{a2}I_{a2}^{*}]$$

$$S_{pu}=I_{a1}(mag)$$

$$SC\ MVA=S_{pu}\ x\ S_{base}$$

$$=S_{base}/|Z_1+Z_2|$$

B. LLLG fault

All the three phases get shorted and then connected to ground

Symmetrical fault is balanced

$$\text{Voltage across } Z_f = 0$$

$$I_a=I_b=I_c=E/Z_1+Z_f$$

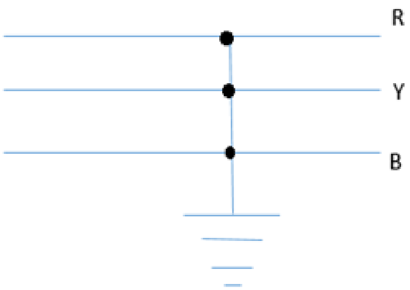


Fig.6.LLLG fault

IV.UNSYMMETRICAL FAULT

A. Single line to ground fault

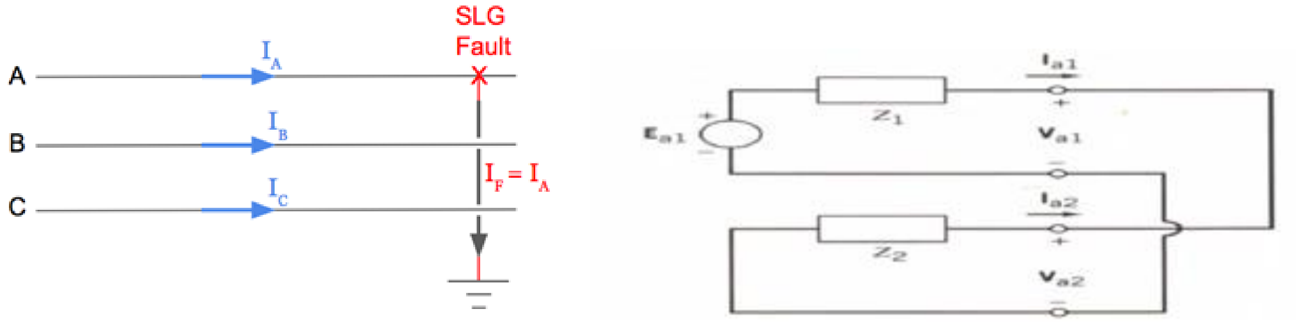


Fig.7.SLG Fault

We assume that fault occurs under no-load condition i.e. current before fault occurrence is zero. Due to unbalanced nature of power system in unsymmetrical fault, there is positive negative and zero sequence currents.

Fig.8.Symmetrical component circuit diagram of LG fault

Voltage at fault point:

$$V_a=I_fZ_f=I_aZ_f$$

$$I_{a1}(3Z_f)$$

From circuit

$$I_{a1=}1/|Z_1+Z_2+Z_0+3Z_n+3Z_f|_{pu}$$

$$I_{a1}=3I_{a1}$$

Short circuit MVA

$$S_{pu}=I_{a1}(pu)$$

$$\text{SC MVA}=I_{a1}(pu)\ x\ S_{base}$$

B. Line to Line fault

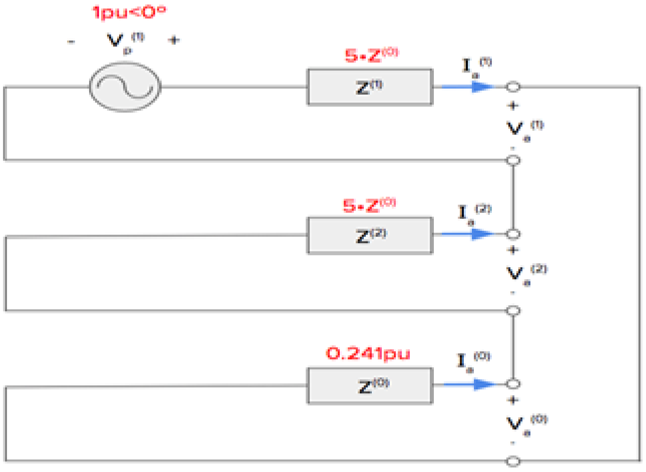


Fig.9.Symmetrical components circuit diagram of LL fault

Symmetrical component of voltage

$$\begin{bmatrix} v_{a_0} \\ v_{a_1} \\ v_{a_2} \end{bmatrix} = \begin{bmatrix} 1 & 1 & 1 \\ 1 & \alpha & \alpha^2 \\ 1 & \alpha^2 & \alpha \end{bmatrix} \begin{bmatrix} v_a \\ v_b \\ v_b - I_b z_f \end{bmatrix}$$

$$V_{a1}\text{-}V_{a2}=I_{a1}Z_f$$

$$I_{a1}(pu)=1/|Z_1+Z_2+Z_f|_{pu}$$

Fault current:

$$I_b=-j\sqrt{3}I_{a1}$$

C. LLG Fault

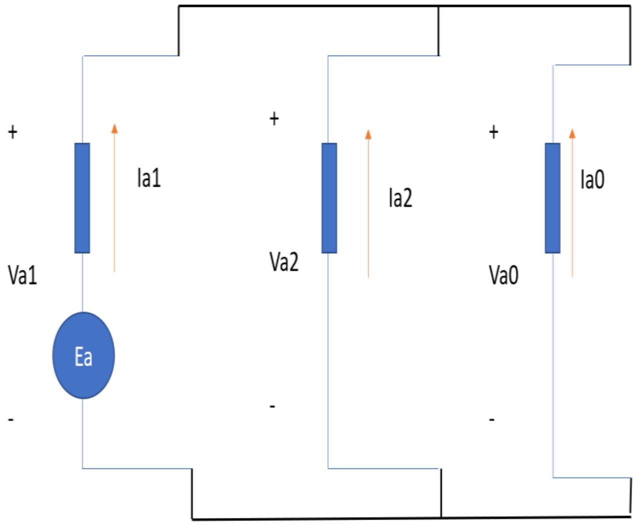


Fig.10.Symmetrical component diagram of LLG fault

$$I_a=E/Z_1+Z_2||(Z_0+3Z_n+3Z_f)$$

In per unit :

$$Ea1=1pu$$

$$I_{a1}(pu)=1/|\ Z_1+Z_2||(Z_0+3Z_n+3Z_f)|_{pu}$$

$$Ia0=-I_{a1}Z_2/Z_2+Z_0+3Z_n+3Z_f$$

V. FAULT ANALYSIS ON DISTRIBUTION FEEDERS

For conventional distribution feeders, the substation is the only source of power, and since the substations are usually away from big generation units, the fault current transients do not have the initial high “sub transient component” that one can see in a fault current of the transmission system. Therefore, the fault current is usually approximated by its steady-state value. Thus, the feeder can be represented by a steady-state model, in which the substation is represented by a Thevenin equivalent (i.e., a voltage source behind the source impedance), and the lines are represented by their series impedances. The loads are usually neglected, but if needed, loads can be represented by their equivalent impedances. The corresponding equivalent circuit can then be analyzed by using the nodal equation

$$[Y_f]V_f=I_{inj}$$

where is the node admittance matrix, is the voltage at each node, and is the current injected at each node. This model can be for equivalent single phase or can be extended for three-phase analysis especially to include the mutual coupling effects. If there are conventional generators on the feeder, the above feeder model can be extended easily by using the simple Thevenin equivalent models for the generators. For inverter interfaced DGs, the same technique cannot be applied, the inverter alters the generator response considerably. Therefore, a new approach is needed in order to incorporate IIDGs into the fault analysis.

Emerging distributed generation technologies make it more likely that more and more distributed generators (DGs) will be connected to the utility distribution feeders and supply power to the system in the near future. To facilitate the interconnection of DGs to a distribution system, standards are being developed. But an engineering analysis is usually needed to assess the impact of the DG on the operation of the system, especially for DGs that supply about 10% or more of the feeder load . One of the major impacts of a DG on a feeder will be during the fault conditions, as the DGs will contribute to the fault current. The fault contribution from DGs may have a major impact on the protection of the feeder . As it is pointed out in , the fault contribution from a single small DG unit may not be large; however, the aggregate contributions of many small units, or a few larger units, can alter the short-circuit levels enough to cause protective devices to malfunction. Higher fault currents will especially affect the Reclosers (RC) on the feeder. For example, extra fault current from an upstream DG may bring the fault current seen by the RC to a level higher than the RC’s maximum interrupting current limit and thus expose the RC to mechanical and thermal stresses that are beyond its limits. Extra fault currents from DGs will also impact the fuse operation, as they will cause the fuses to clear sooner than designed

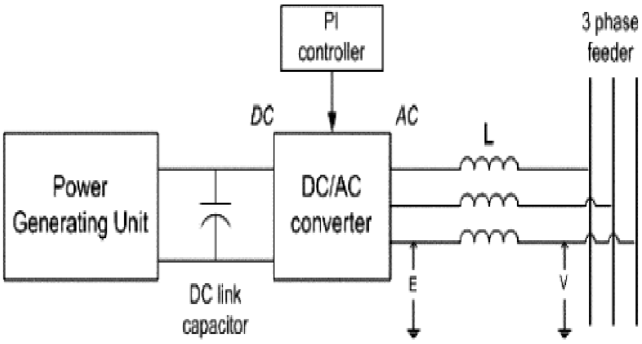
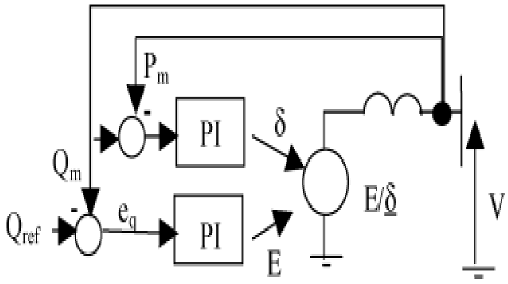
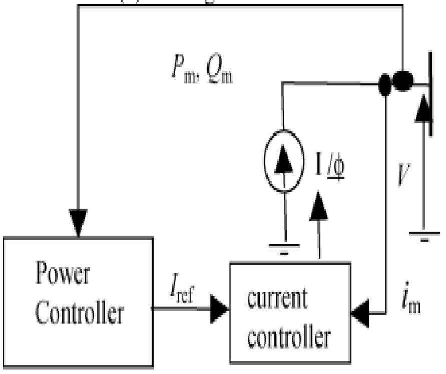


Fig.11.Main components in IIDG



(a) voltage control scheme



(b) current control scheme

Fig.12. IIDG representation for fault analysis under two control schemes

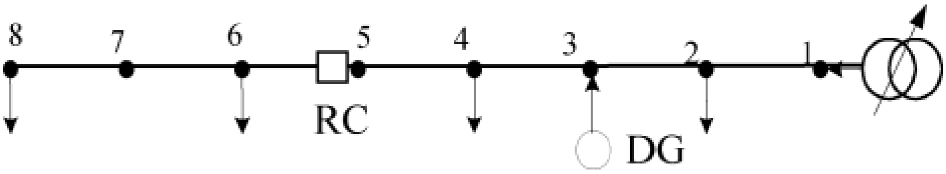
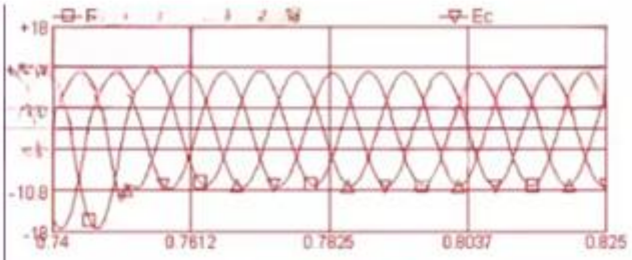
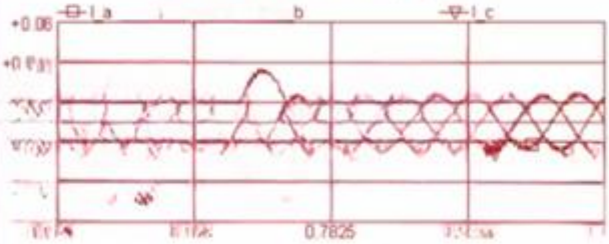


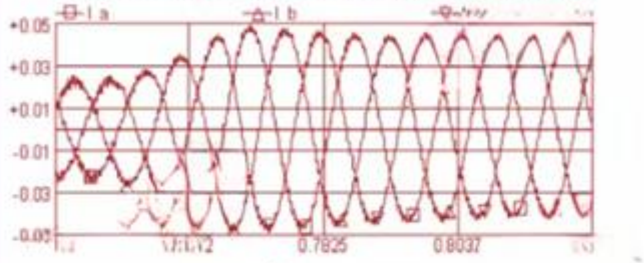
Fig.13.Prototype Feeder



(a) [illegible]hase voltage profile



(b) current profile under voltag[illegible] sch[illegible]



[illegible] current profile under curren[illegible]

Fig.14. IIDG response to a remote fault under two different control schemes (fault is at t=0:75 s, time in s, currents in kA, and voltage in kV)

DG Representation Fig. 11 shows the main components of an IIDG. The power generating unit (PGU) produces the dc power and could be a fuel cell, micro turbine, or a photovoltaic. The dc voltage is then converted via an inverter to three-phase ac voltage. The controller on the inverter regulates the inverter active and reactive power output around the desired set point. Due to the dc link capacitor between the PGU and the converter, the dc output voltage will remain almost constant during short transients, and therefore, we can assume a constant dc input voltage for the converter. Hence, during a transient, the IIDG response depends mainly on the inverter controller. There are mainly two control schemes used in practice. In the voltage control-based scheme, the controller helps the inverter to synthesize a three-phase balanced ac voltage at the inverter terminals (with some harmonics that can be neglected for control purposes). To regulate the real and reactive power output of the IIDG, the controller adjusts the amplitude and the phase of this synthesized inverter voltage ( ) with respect to its terminal voltage ( ). Therefore, the voltagecontrolled equivalent circuit, shown in Fig. 12(a), can be used to represent the IIDG during the transient period for this control scheme. As the figure indicates, in practice, a simple PI-type controller is used for regulating the power output of the DG. The main disadvantage of this scheme is that the current cannot be directly controlled. Hence, the newer controllers may use a current control scheme. This control scheme, as Fig. 2(b) illustrates, uses two loops; the inner loop controls the current output of the DG and the outer loop regulates the power output. The outer power controller acts Fig. 13. Prototype feeder. Fig. 14. IIDG response to a remote fault under two different control schemes (fault is at t=0:75 s, time in s, currents in kA, and voltage in kV). like a supervisory controller and determines the current reference for the fast inner current controller. To illustrate the response of an IIDG to a fault, we simulated a case that corresponds to an IIDG connected upstream of a RC on a feeder, which is illustrated in Fig. 3. In this case, we are interested in the contribution of the DG to the fault current the RC will see. Fig. 4 shows the DG current and voltage waveforms for a fault at the end of the feeder when DG operates under the two different control schemes. Fig. 4 shows that under the voltage control scheme, the initial current overshoot is high and then controller brings the current to a steady state rather quickly, within a few cycles. Under the current control scheme, the current increases much slower and then decreases back to the steady-state value rather slowly. The slow corrective response under current control is mainly due to the slow response of the outer power control loop. However, the current is much controlled under this scheme. The current contribution under current control can be even more limited for solar applications where the outer power control loop is not used or is very slow. Note that this prototype scenario corresponds to the IIDG fault contribution for a remote fault, and thus the contribution of fault current is within the maximum current rating of the converter, which is typically twice the normal rating. faults, the IIDG is usually equipped with a protection scheme that turns the converter off when the current reaches the maximum limit . Thus, this fault limiting needs to be considered as part of the fault analysis. The figure also illustrates that the fault contribution of an IIDG will be higher especially during the transient period (first 5–10 cycles) if the IIDG is under voltage control scheme than under current control scheme. Therefore, in this paper the focus will be on the IIDGs with voltage control schemes. However, the method proposed here can be also adopted for the current controlled case.

VI.MICROGRID

A microgrid usually consists of small segments of a distribution network connected to local DG units and loads. solar arrays are each connected to three-phase inverters and provide a total of 2,256 kW. The wind generators provide an additional 500 kW to the grid. During islanded operations, additional generation and load following is provided by a 300 kW diesel generator. The one line diagram of the system is shown in Fig.15

VII. SIMULATION OF THE MICROGRID SYSTEM

we evaluate the maximum and minimum fault currents at each bus in the microgrid. The four major faults—single line to ground, line to line, double line to ground, and three phase faults—are initiated in the system 0.1 second after the system had reached steady state and is sustained for another 0.4 second. This allows the rms values of the symmetric fault currents to be measured. The fault impedance is chosen as 1mΩ. The system is only simulated in the islanded mode as the fault currents at each bus for the original system configuration are given in . Faults with DG source contributions in grid-connect mode can therefore be easily computed using superposition. Fault currents are measured on both the high (closest to substation) and low (farthest from the substation) side of the fault as most locations had generation on both sides. Currents are also measured at the high and low buses, (where high and low mean the same as above) that would need to have backup protection if the devices at the particular bus should fail. Additionally, a three phase power flow study is conducted for three cases: (1) on the original system, (2) on the grid connected microgrid system, and (3) on the islanded system with the utility system isolated to compare the operating currents with the fault currents.

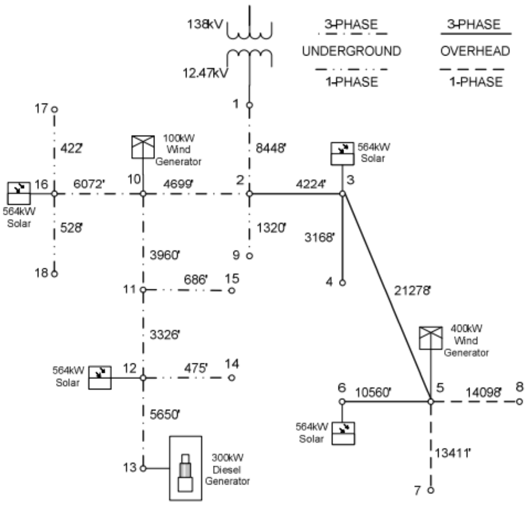


Fig.15. One line diagram of the microgrid with added DG sources

VIII. CONCLUSION

In this paper we analyzed different types of fault using symmetrical components and studied how fault analysis can be used in microgrids to investigate fault currents and how fault analysis can be applied to IIDGs.We can figuring out that around 15 - 20% of 46.68 KA .fault current can be reduced by putting reactor in between 24 and 26 bus of 220KV. In this paper an attempt is made to review of the Fault current limiting techniques and its role in power system networks. In major cases, the location of FCL installation is at bus tie because it gives reliable operation of the system and optimizes fault current to the minimum level.Every device obeys Newton's first law of motion and the VCB movable contacts are not exceptions. Under heavy loads such as short-circuits, opening and closing of circuit breaker contacts generates an arc around the contact regions which heats up the contacts. If the fault is not cleared early enough by protective elements such as the circuit breaker, severe damages would be done on the system which will not only be catastrophic and extremely dangerous, but also costly.It is therefore, extremely important to perform fault studies on every power system, in order to determine the ratings of the respective protective elements employed. The importance of CBs in power systems is extremely important and the VCB in particular has a very good fault error clearing capabilities, ease of installation and environmentally friendly. Concerned industries should pioneer research programs in the area of development of high voltage VCBs in our institutions and research centers. Every component of our power system should be protected from fatal and total failures usually caused by faults and accidents on the transmission and distribution sections. To protect failures in our national grid, power system protection engineers should be employed to examine and perform adequate fault study on the system.

IX.REFERENCES

[1]. T. C. Green and J. D. McDonald, "Modelling and Analysis of Fault Behaviour of Inverter Microgrids to Aid Future Fault Detection," Proceedings of the IEEE International Conference on System of Systems Engineering, 2007, pp. 16-18.

[2]. H. Nikkhajoei and R. H. Lasseter, "Microgrid Protection," Proceedings of IEEE Power Engineering Society General Meeting, 2007, June 2007, pp. 1-6.

[3]. J. C. Gomez and M. M. Morcos, “Coordinating overcurrent protection and voltage sags in distributedgeneration systems,” IEEE Power Eng. Rev., vol. 22, no. 2, pp. 16–19, Feb. 2002.

[4]. Yang, J.; Fletcher, J.E.; O’Reilly, J. Short-Circuit and Ground Fault Analyses and Location in VSC-Based DC Network Cables. IEEE Trans. Ind. Electron. 2012, 59, 3827–3837.

[5]. Guo, C.; Ye, C.; Ding, Y.; Wang, P. A Multi-State Model for Transmission System Resilience Enhancement Against Short-Circuit Faults Caused by Extreme Weather Events. IEEE Trans. Power Deliv. 2021, 36, 2374–2385.

[6]. Al Mtawa, Y.; Haque, A. Clustering-Coefficient Based Resiliency Approach for Smart Grid. In Proceedings of the 2021 IEEE International Wireless Communications and Mobile Computing Conference (IWCMC), Harbin, China, 28 June–2 July 2021.

[7]. Abir, S.M.A.A.; Anwar, A.; Choi, J.; Kayes, A.S.M. IoT-Enabled Smart Energy Grid: Applications and Challenges. IEEE Access 2021, 9, 50961–50981.

[8]. Parsi, M.; Crossley, P.; Dragotti, P.L.; Cole, D. Wavelet Based Fault Location on Power Transmission Lines Using Real-World Travelling Wave Data. Electr. Power Syst. Res. 2020, 186, 106261.

[9]. Huang, W.; Luo, G.; Cheng, M.; He, J.; Liu, Z.; Zhao, Y. Protection Method Based on Wavelet Entropy for MMC-HVDC Overhead Transmission Lines. Energies 2021, 14, 678. [Google Scholar] [CrossRef]

[10]. Bragatto, T.; Cerretti, A.; D’Orazio, L.; Gatta, F.M.; Geri, A.; Maccioni, M. Thermal Effects of Ground Faults on MV Joints and Cables. Energies 2019, 12, 3496.

[11]. Lee, S.R.; Ko, E.Y.; Lee, J.-J.; Dinh, M.-C. Development and HIL Testing of a Protection System for the Application of 154-KV SFCL in South Korea. IEEE Trans. Appl. Supercond. 2019, 29, 1–4.

[12]. Medeiros, R.P.; Costa, F.B.; Silva, K.M.; Popov, M.; de Chavez Muro, J.J.; Lima Junior, J.R. A Clarke-Wavelet-Based Time-Domain Power Transformer Differential Protection. IEEE Trans. Power Deliv. 2021, 37, 317–328.

[13]. Mukherjee, N.; Chattopadhyaya, A.; Chattopadhyay, S.; Sengupta, S. Discrete-Wavelet-Transform and Stockwell-Transform-Based Statistical Parameters Estimation for Fault Analysis in Grid-Connected Wind Power System. IEEE Syst. J. 2020, 14, 4320–4328.

[14]. Vanitha, V.; Hussien, M.G. Framework for Transmission Line Fault Detection in a Five Bus System Using Discrete Wavelet Transform. Distrib. Gener. Altern. Energy J. 2022, 525–536.

[15]. Namdev, P.P.; Sudhir, M.P.; Shantaram, R.D.; Goutam, M.R.; Shankar, S.V.; Palake, S.A. Transmission Line Fault Detection with Mini WeatherStation Using IoT. Asian J. Converg. Technol. (AJCT) 2021, 7, 130–133.

[16]. Kunj, T.; Ansari, M.A.; Vishwakarrma, C.B. Transmission Line Fault Detection and Classification by Using Wavelet MultiresolutionAnalysis: A Review. In Proceedings of the 2018 International Conference on Power Energy, Environment and Intelligent Control (PEEIC), Greater Noida, India, 13–14 April 2018; pp. 607–612.

[17]. Takagi, T.; Yamakoshi, Y.; Yamaura, M.; Kondow, R.; Matsushima, T. Development of a New Type Fault Locator Using the One-Terminal Voltage and CurrentData. IEEE Trans. Power Appar. Syst. 1982, 101, 2892–2898. [Google Scholar] [CrossRef]

[18]. Arora, C., Swarnkar, N. K., & Sharma, R. (2018). TLBO Based Load Frequency Controller. RESEARCH JOURNALS, 4.

[19]. Zadeh, L.A. Fuzzy Logic. Computer 1988, 21, 83–93.

[20]. Bhat, A.U.Q.; Prakash, A.; Tayal, V.K.; Choudekar, P. Three-Phase Fault Analysis of Distributed Power System Using Fuzzy Logic System (FLS). In Advances in Smart Communication and Imaging Systems; Agrawal, R., Kishore Singh, C., Goyal, A., Eds.; Springer: Singapore, 2021; pp. 615–624. [Google Scholar]

[21]. Jiao, Z.; Wu, R. A New Method to Improve Fault Location Accuracy in Transmission Line Based on Fuzzy Multi-Sensor Data Fusion. IEEE Trans. Smart Grid 2019, 10, 4211–4220. [Google Scholar] [CrossRef]

[22]. Soni, A.K.; Yadav, A. Fault Detection and Classification of Grid Connected Wind Farm (DFIG) Using Fuzzy Logic Controller. In Proceedings of the 2021 IEEE International Power and Renewable Energy Conference (IPRECON), Kollam, India, 24–26 September 2021; pp. 1–6.