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Effect of Transformer Connection on Protection of Feeder Connected With Distributed Generators

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Abstract — *Energy demand is expected to grow very rapidly and Distributed Generation (DG) or the alternate energy systems is expected to play an increasing role in the future of the power systems. The DG is defined as small-scale generation and can be connected at load points. DG is increasingly becoming more important in the power system because of its high efficiency, small size, low investment cost, modularity and most significantly, its ability to exploit renewable energy resources. After connecting distributed generation, part of the system may no longer be radial, which means coordination might not hold good as the traditional radial nature of the power distribution system is now converted into a multi source unbalanced network. DG may bring about reliability degradation, instead of reliability enhancement, due to relay-relay miscoordination. Current literature covers issues related with DG connection & mainly impact of DG interfacing transformer connection on IDMT over current relay. This is illustrated by test results on a system simulated using PSCAD.*

Key words- Distributed generation, Issues related to DG, Impact of transformer connection

I. Introuction

DGs are becoming increasingly popular due to their low emission, low noise levels and high efficiency. One of the main advantages of DG is their close proximity to the customer loads they are serving [6]. The distributed generation also reduces green house gas emission addressing pollutant concerns by providing clean and efficient energy. Distributed generation is the key to meeting growing demands of electricity and provides benefits to customers, utility and market. DG technologies include reciprocating engines, photovoltaic, fuel cells, combustion gas turbines, micro turbines and wind turbines [1]. The technologies are also called alternate energy systems as they provide an alternative to the traditional electricity sources i.e. oil, gas, coal, water etc. and can also be used to enhance the current electrical system. The installation of DG in the network has technical, environmental and commercial challenges. Additional technical challenge is uncertainties associated with generation technologies which may become outdated resulting in reduced project life span. This could be due to unsustainably high maintenance operational costs as a result of obsolescence. Environmental challenges depend on the generation technology chosen, for example, wind turbines may not be sited in certain areas even if the wind resource is favorable. Commercial challenges are the changing market conditions and regulations: energy and fuel prices, operating costs, maximum operating profit, incentive schemes and variation of load demand from the projected figures.

II. Impacts Of Distributed Generation

Interconnecting a DG to the distribution feeder can have significant effects on the system such as power flow, voltage regulation, reliability etc. A DG installation changes traditional characteristics of the distribution system. Most of the distribution systems are designed such that the power flows in one direction. The installation of a DG introduces another source in the system. When the DG power is more than the downstream load, it sends power upstream reversing the direction of power flow and at some point between the DG and substation; the real power flow is zero due to back flow of power from DG [1]. A DG installation increases the complexity of the system and impacts the power flow and voltage conditions of the system. The planning of the electric system comprises of several factors: types of DG, capacity and number of the DG units, the installation location etc. Depending on these factors, the DG can have positive or negative impacts on the system. When the DG is attached downstream, it can confuse the voltage regulator by setting a voltage lower than the required value. Thus careful coordination between the DG and voltage regulator is necessary. Properly coordinated DG can improve the voltage profile of the system and enhance the power system stability [4]. Placing the DG at optimal location can reduce the losses on the feeder. The DG can also improve the reliability of the system by serving as a backup generation for some customers in case of interruptions from the utility. The major technical benefits are: reduced line losses; voltage profile improvement; reduced emissions of pollutants; increased overall energy efficiency; enhanced system reliability and security; improved power quality; relieved T&D congestion; Standby Capacity or Peak Use Capacity; Grid support; shorter construction times; Fuel flexibility [3], [4]. At the same time network also offers few technical shortcomings like: Costs of connection; Cost of metering; Increase in Fault current; Increase in Harmonic contents; Change in Islanding Procedure; Change in Protection Philosophy; Stability; Reliability indices [1], [3], [4].

III. Impact Of Transformer Connections

The selection of the interconnection transformer connection has a good impact on how the dispersed generator will interact with the utility system. The type of transformer employed has an impact on the grounding perceived by the utility primary system and for the generator to appear as a grounded source to the utility primary distribution systems, the transformer must be able to pass a ground path from the low voltage to the high voltage side, which is commonly called as zero-sequence path. There is no universally accepted “best” connection. Commonly used connections with their effect on over-current relay, in terms of time of operation of breaker with DG & without DG are listed in result tables. Each of these connections has advantages and disadvantages to the utility with both circuit design and protection coordination affected. Each connection should be addressed by the utility as they establish their interconnect requirements.

IV. SIMULATION

Single line diagram is shown in figure-1.Feeder is energized by utility generator trough a transformer. Load is connected at far end of feeder. DG is also connected at end of feeder through proper interfacing transformer. Earlier without DG, a system was radial & relay setting was done accordingly. With introduction of DG in system, now system became bi-directional. DG will also contribute in fault current which may not keep system protection reliable & selective.Table I gives system specification. Normal and short circuit characteristics of the feeder with and without distributed generators were analyzed. The analysis is being used to determine how over-current protection must be modified to properly protect distribution systems with DGs. Faults are created at four points on feeder & effect of DG can be visulised with time of operation of circuit breaker for different faults.Table II, III & IV shows results of PSCAD simulation.

V. Result Discussion

High Side Delta or Ungrounded Wye: An advantage of this connection is that there is no source of zero sequence current to impact the utility ground relay coordination.

High Side Grounded Wye/ Low Side Delta or High Side Grounded Wye/ Low Side Grounded Wye: This connection establishes a zero sequence current source for ground faults on the distribution system, which could have a significant impact on the utility’s ground relay coordination. With the addition of the generator interconnection transformer this unbalance will be divided between the utility transformer neutral and the generator interconnect transformer. Thus relay takes more time. Also any fault between DG & DG interfacing transformer will not be seen by utility side breaker

From fig.2, any fault in system is sensed by utility side breaker only. Utility gets isolated but DG still feeds fault current as circuit breaker is not provided at the end of feeder.

The sensitivity of the feeder protection is reduced by inclusion of DG as seen from table IV. In other words, fault appears farther away as a result of the DG.

As seen in fig. 3, Fault current is decreases as location is changed from F1 to F4 i.e. as moving away from utility.

Sr. no.	Electrical element	Specification
1	Utility generator(G1)	25MVA, 66KV,50Hz
2	Utility Transformer (T1)	20MVA, 66KV/11KV, Delta-star(Neutral grounded)
3	Feeder 1	(0.06+j0.002)Ω, Length : 2KM
4	Feeder 2	(0.06+j0.002)Ω, Length : 2KM
5	Distribute generator (G2)	1MVA, 3.5KV, 50Hz
6	DG Transformer(T2)	0.5MVA, 3.5KV/11KV
7	Load	2MW, 0.1Mvar,11KV,50Hz

Table I - System Specification

A-G	No DG	D-D	D-Y(g)	Y(g)-Y(g)
F1	0.000006	0.053726	0.172453	0.127828
F2	0.000015	0.051179	0.163765	0.124626
F3	0.000018	0.050134	0.164964	0.119614
F4	0.000025	0.031040	0.005385	0.033368

Table II - Results of IDG (Fault) in ka for A-G fault

A-G	No DG	D-D	D-Y(g)	Y(g)-Y(g)
F1	10.55851	10.7295	10.72379	10.7486
F2	4.287525	5.130140	5.362645	5.112497
F3	2.615552	3.150784	3.432807	3.128929
F4	0.160736	0.212000	0.235084	0.211824

Table III - Results of IT (Fault) in ka for A-G fault

A-G	No DG	D-D	D-Y(g)	Y(g)-Y(g)
F1	0.068750	0.066240	0.058500	0.066250
F2	0.108750	0.075500	0.069250	0.076250
F3	0.132000	0.091750	0.076250	0.092000
F4	0.305500	0.219000	0.186000	0.219250

Table IV - Results of TOP in seconds for A-G fault

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VI. Conclusion

With a DG in the system, the currents during the fault are increased compared to a case without DG. Relay settings must be modified accordingly before connection of DG in system to maintain reliability. Care must be taken to set relay whenever DG is inserted in persisting system to maintain reliable operation of protective devices.

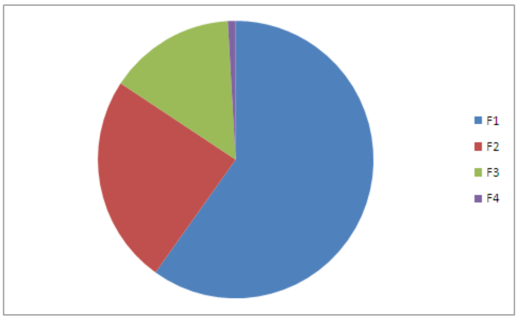

Fig. 3: Intensity of fault at different locations for IT (Fault)

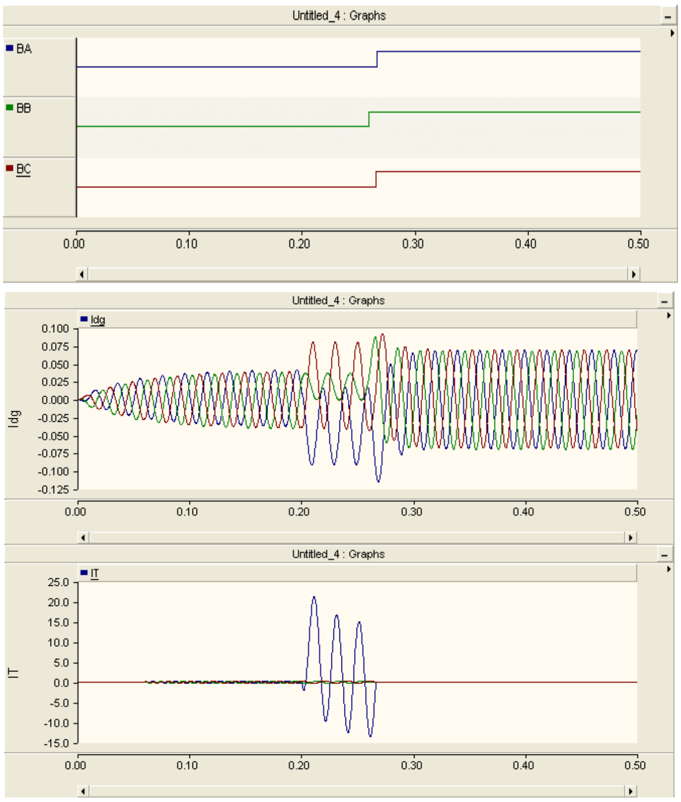

Fig. 2 Waveforms of & breaker operation current of DG & Current of Utility for A-G fault at F1 location.

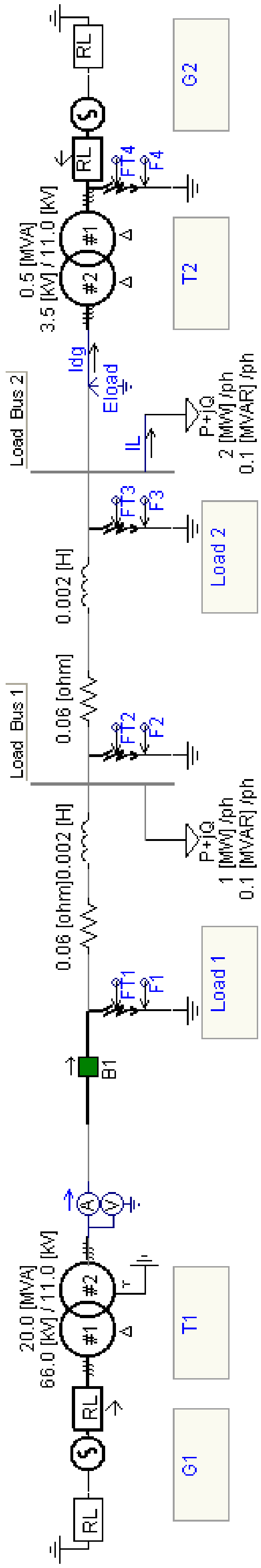

Fig. 1 Single line diagram

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