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Simulation of Battery Storage Photovoltaic-Wave Energy Hybrid Renewable Power Generation Systems with Protection

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***Abstract* - In this paper, protection issues due to distributed generation integrated into the distribution system Protection of distribution system in to the incidence of distributed generation have been achieve by designing intelligent controllers under faulted conditions the performance analysis of wind turbine, micro turbine, solar, PEMFC and SOFC as a distributed generation units are considered. In this study the simulation models includes wind power is driven by an induction machine. Models are designed, modeled and simulated using MATLAB-SIMULINK software such that it can be suitable for modeling induction generator, rectifier-inverter configurations. To analyze more deeply the performance of the different distributed generations, under normal and fault conditions. Simulation results obtained the good performance of the DG units under normal and fault conditions in the power distribution system and also power quality problems are involved with different controllers like PID, Fuzzy and model reference adaptive.**

***Index Terms* - Distribution, DSTATCOM, MATLAB/ SIMULINK, Power quality problems, Non-linear loads.**

INTRODUCTION

The three major challenges at present in the world, i.e. protection of environmental, conservation of energy resources and development of sustainable [1]. Most important issue is to sustain the utilization of energy for customers without causing depletion of the natural energy resources rapidly and damage the environmental. In the form of electrical energy, the utilization of Distributed Generation (DG) has the new era. To the use of small generating units, DG are related and usually the rating is less than 10 MW for which transmission or distribution systems are also connected to. The new and latest technologies such as fuel cells, wind energy, micro hydro power sources and solar photovoltaic's makes DG more and more economical and popular [2].

To provide the most economical solution for load growth Distributed Generation (DG) is considered. The growth in load is due to impacts such as overload or low voltage is expected to be obtained by simulating the DG in different weak and strong locations. There are many series of problems in different locations, where to provide, the DG. The necessary control to mitigate the problems of voltage drop. According to the theory, the DG is able to ensure the minimum cost for the solution to the optimum problem and the simulation model will be considered to use the required voltage control. DGs are placed in the circuit which may lead to drastic improvements in terms of reliability and losses of the electrical power system. The necessity of a DG into a distribution system introduces the change in the level of the fault current system which causes Various problems in the power protection system, such as protective devices false tripping, protection blinding, a short circuit levels increase and decrease, undesirable network islanding and out of synchronism reclosers.

Protection Issues with DG

The general problem which is integrated with DG are planned in existing networks distribution systems as passive networks, carries unidirectional power from the central generation (HV level) downstream to the consumer loads at MV/LV level. The protection system design in common MV and LV distribution networks is determined by a passive paradigm, i.e. no generation is expected in the network.

With distributed sources, the networks get active and conventional protection turns out to be unsuitable.

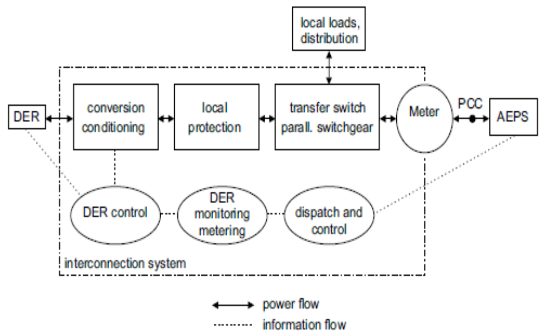

Fig 1: Block Diagram of Distribution system

If distribution generations are more in some areas of the distribution network, and they are also interconnected into various buses as shown in figure 1. Analyses are found the same control mode of the distributed generators which have the same functionality, so the equivalence of the sources with the distributed generators in the system are considered. The impact for analyzing distribution network by micro-grid, where the equivalence is adopted. The overall distributed generators in the control area can be seen a new larger generator, the rating of the new generator can be considered.

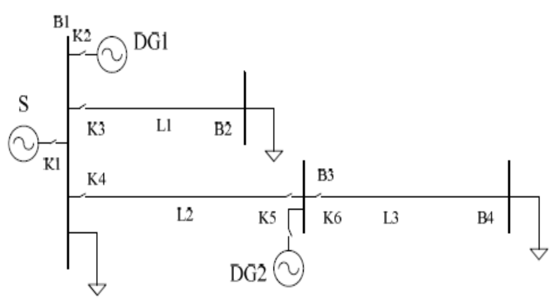

Fig 2: Grid-connected system

The system generally operates at source side at the grid-connection state normal state; network which consists of distribution can also supplies to relative parameters like stable basic voltage and frequency, so all VF control generators may supply little power output or exit. But when micro-grid operates at island mode, VF control generators must keep the power of island system balanceable, so they often need compensate the power loss. After the connected island is to use in distribution network, the units which are used for energy storage (usually VF control generators) need to be recharged, then the control of VF generators which varies to the load as far as the energy storage equipment is fully charged.

Utility Required Protection

The schemes of Protection may be complex or simple. The protection which is to be satisfied with in the maximum conditions or limits for both utility and generator needs with respect to regulatory requirements. Many DG installations utilities will require to conform in certain areas. The utility may provide detailed requirements in the following areas:

- Interconnection transformer of the Winding configuration
- Relays of utility-grade interconnection are in General requirements
- Requirements of the CT and VT
- Functional protection requirements (81O/U, 27 and 59)
- Speed of operation for Settings of some interconnection functions

Table 1: Different Transformer connections and their advantages and problems

Low Voltage (LV)	High Voltage (HV)	Problems	Advantages
Delta Gnd-Wye Delta	Delta Delta Wye	Can supply the feeder circuit from an ungrounded source after substation breaker 'A' trips causing overvoltage	Provide no ground fault back-feed for fault at F1 & F2. No ground current from breaker A for a fault at F3
Delta	Gnd-Wye	Provides an unwanted ground current for supply circuit faults at F1 and F2	No ground current from breaker A for faults at F3. No overvoltage for ground fault at F1
Gnd-Wye	Gnd-Wye	Allows source feeder relaying at A to respond to a secondary ground fault at F3	No overvoltage for ground fault if the gen neutral is Y-connected with a low impedance ground

Table 2: Transformer connections based on the System voltage

System Voltage (kV) – Secondary	Generation Size	Preferred Interface Transformer High voltage side : Low voltage side (HVS:LVS)
27.6 kV	1 -2 MW	Gnd-wye : Delta Delta : Gnd-wye Gnd-wye : Gnd-wye
27.6/12/8 kV	200 kW – 1 MW	Gnd-wye : Gnd-wye Gnd-wye : Delta Delta : Gnd-wye
27.6/12/8/4 kV	50 kW – 200 kW	Gnd-wye : Gnd-wye
27.6/12/8/4 kV	10 kW – 50 kW	Gnd-wye : Gnd-wye

The Utility's Primary Distribution System is supplied by substation transformers with high voltage/low voltage winding configurations of either Delta/ Grounded Wye or Grounded Wye/Delta (with a ground referencing transformer on the distribution side). The transformers supplying power to the secondary voltage distribution systems incorporate 3 phase, 4 wire grounded secondaries or, in the case of the single phase systems, neutral grounded center tapped configurations.

CONTROLLER

Design of PID Controller:

It continuously uses for PID controller which calculates the *error value* with the difference between a desired or reference point and a measured or output process variable and includes a correction and it depends on proportional, integral, and derivative terms of the PID controller. The attempt of the controller is to reduce the error over the time by adjust settling time of a *control variable* in this model:

- *P* controller represents the error including the adjustments of the parameters of the controller. For example, if the error may be large and positive value, the control output will may also be large and positive.
- *I* controller considers for the stored values of the system error. For example, if the output current is not strong sufficiently, the error of the integral will accumulate over time, and the controller may respond for applying a stronger action.
- *D* accounts for possible future trends of the error, based on its current rate of change

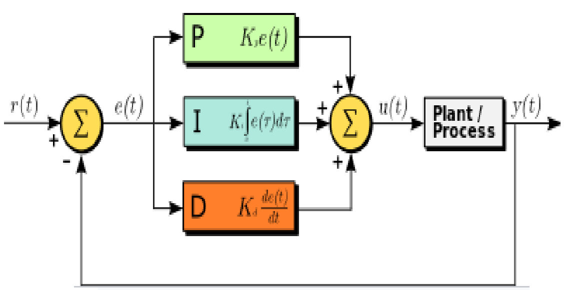

Fig 3: Block diagram of PID controller

Design of FLC controller:

The fuzzy logic controller proposed integration for DG implies Mamdani and Sugeno fuzzy inference system. The sizing of the DG is estimated using fuzzy logic controller i.e. Mamdani type on the primary basis of distribution feeder for better performance parameters such as substation reserve capacity, power loss in feeder with the load ratio, voltage unbalance, and apparent power imbalance, whereas fuzzy logic controller Sugeno type is used to select the location of the DG on the basis of DG output, index of the survivability, and node distance from the substation. The expert system which is fuzzy-based controller which is tested using the MATLAB software, fuzzy logic tool box and sim power system block sets under multi-rules-based decision and multisets considerations as in Figure 4.

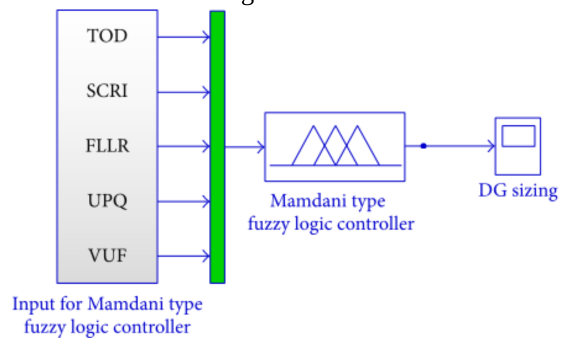

Fig 4: FLC – Mamdani type

The process of Inference process for Mamdani type fuzzy logic controller has method of MIN-MAX aggregation and defuzzification process as standard settings of the SOM. The other setting for fuzzy logic controller is Sugeno type remains the same for defuzzification method Proposed for the Mamdani type inference as shown in Figure 2 has a set of 15 fuzzy rules, which involve all the rules of heuristic for calculating the size of DG in the fuzzification process. In the process of fuzzification, these inputs are converted into logic form in accordance with the membership functions associated. Triangle membership function is adopted for medium value FLLR, UPQ, and VUF, whereas membership functions of trapezoidal are considered for the low and high of the above three variables.

Design of Adaptive controller:

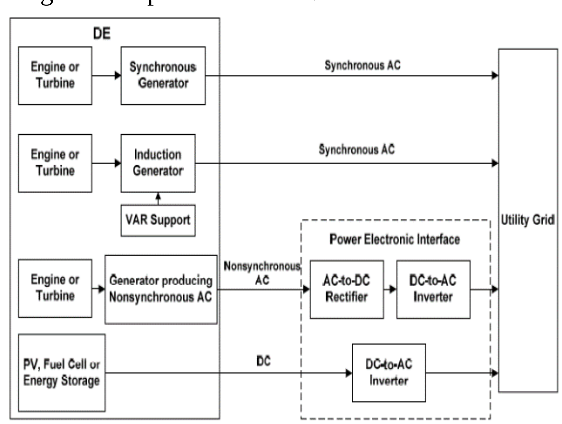

Fig 5: Different DGs connected to the utility grid

If K_P or K_I are not chosen exactly they are obtained appropriately, the response of the system may be poor and may not be reliable at worst conditions, create instability. So preventing a poor system response and optimizing the speed response are desired from the design of the PI controller by setting the goal for creating an hybrid combination of adaptive PI design that can be dynamically adjusting the PI controller parameters in real-time system based on the behavior of the system and configuration. The proposed adaptive PI control method, inspired by the generic adaptive control method in [3][47][48], consists of three procedures:

Determine the DC source voltage of the DE;
Set the initial values, K_P and K_I parameters in the Controller which are; and adaptively adjusted to the controller parameters according to real-time system boundaries. Typically chosen initial Lower gain parameters, K_P and/or K_I, are and only improved after confirming that they do not cause any of the above assumed poor response and instability problems. The controller parameters with a fixed K_P and K_I may not always reach the desired and acceptable output response in power systems where the system load and other conditions are changing constantly.
Without a communication which is centralized and control of the system, to utilize the controller has a self learning capability to adjust K_P and K_I dynamically. The case of Using local voltage requiring an improves as an example, if the control logic shows that the voltage has increased too rapidly, then K_P and K_I will be adjusted to lower values. In addition to performance another advantage is the elimination of an expensive and extensive centralized communications system because the parameters track the locally defined ideal voltage response curve. The sampling rate with the high frequency of sensors and modern power electronics ensures in the simulations and field testing. Hence, the method is known as "adaptive voltage control.

Simulation results

a. Protection by varying external faults like LG, LLG and LLLG faults by varying different controllers:

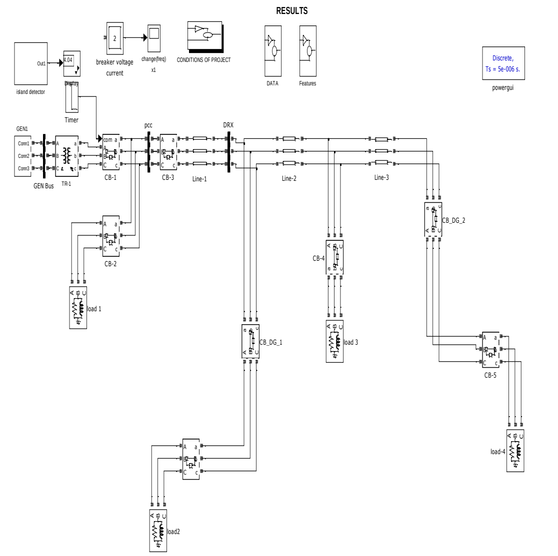

Fig 6: Simulation model with PID controller, Circuit breakers and without DG

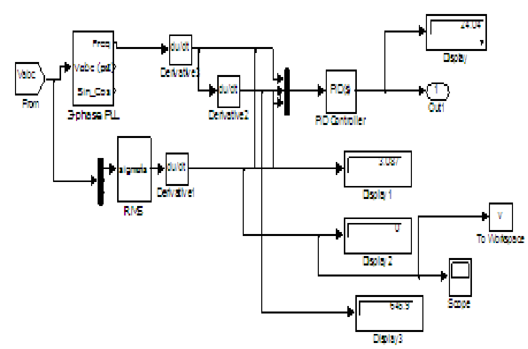

Fig 7: Subsystem of PID controller

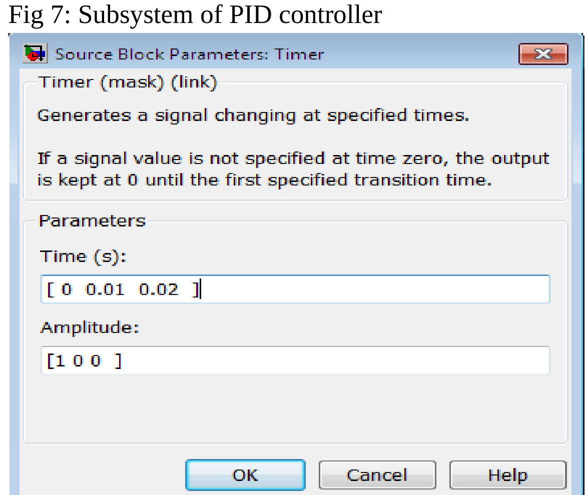

Fig 8: Circuit Breaker timing

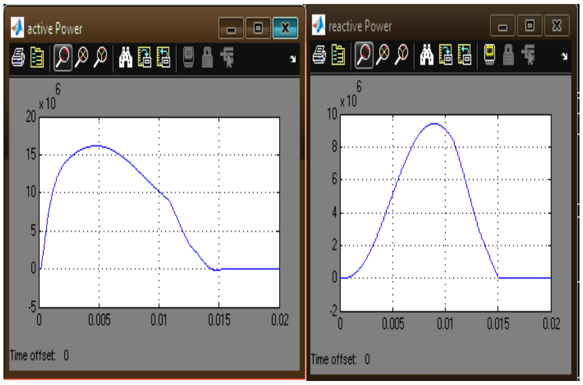

Fig 9: Active and reactive powers versus time

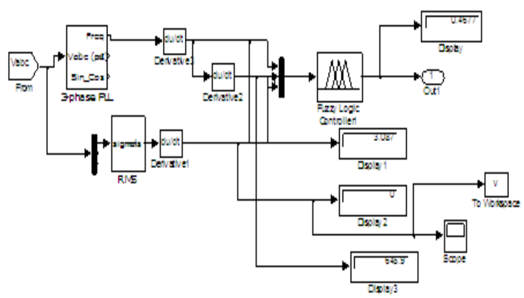

Fig 10: Subsystem of FLC controller

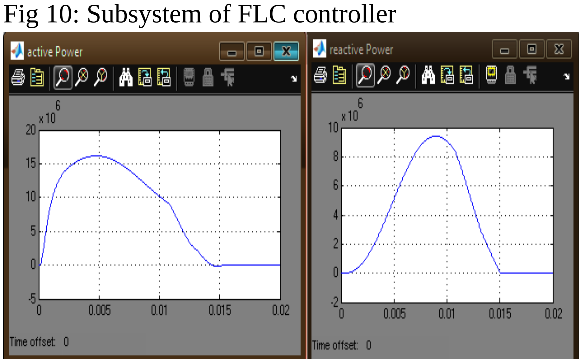

Fig 11: Active and reactive powers versus time

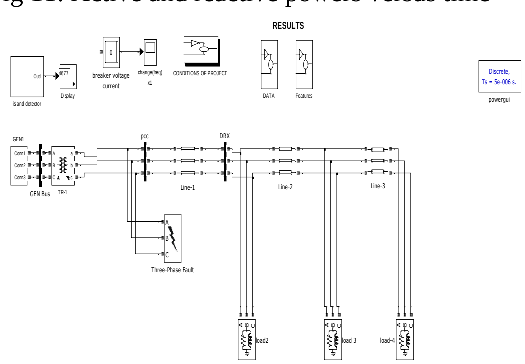

Fig 12: Simulation model with PID controller and without DG

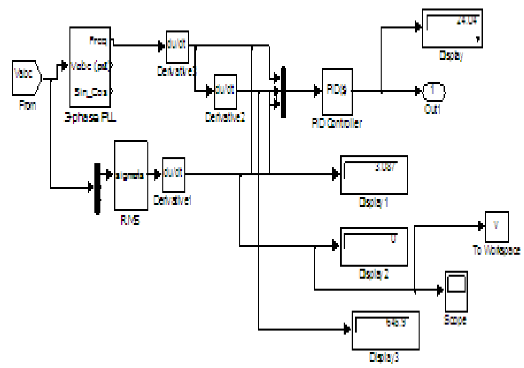

Fig 13: Subsystem of PID controller

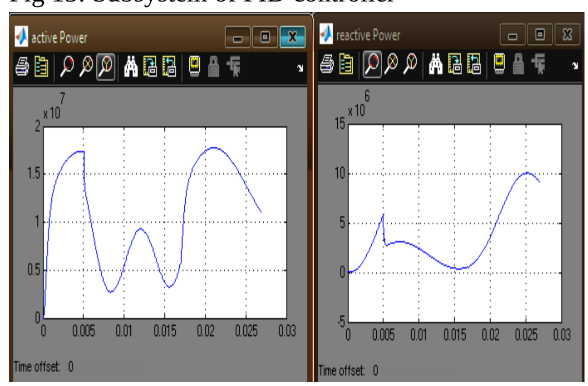

Fig 14: LG fault

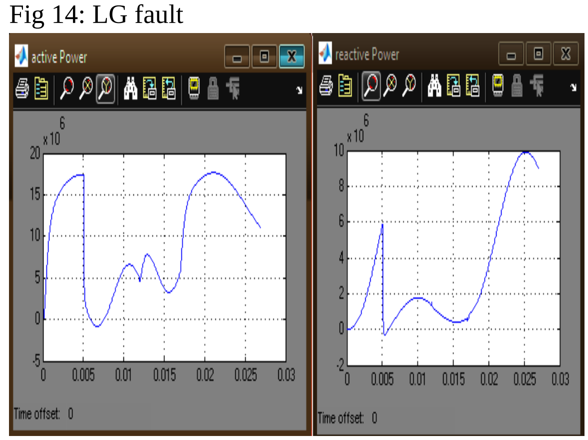

Fig 15: LLG fault

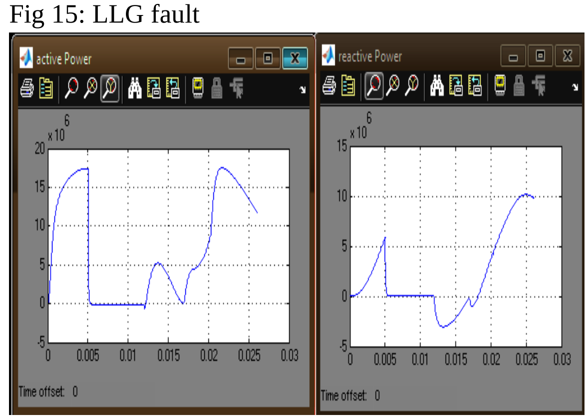

Fig 16: LLG fault

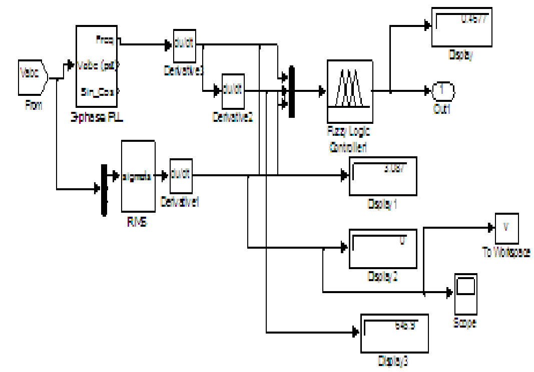

Fig 17: Subsystem of FLC controller

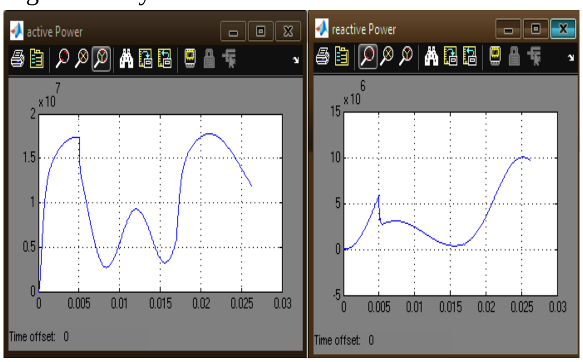

Fig 18: LG fault

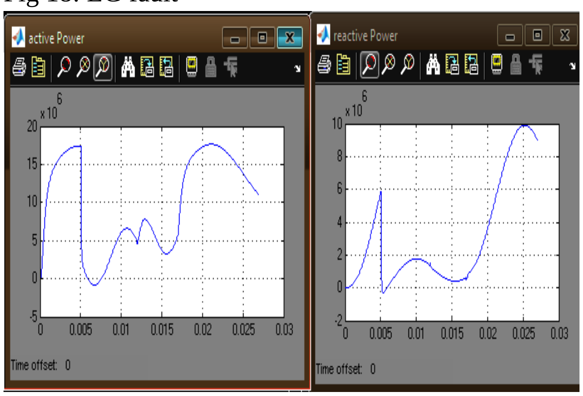

Fig 19: LLG fault

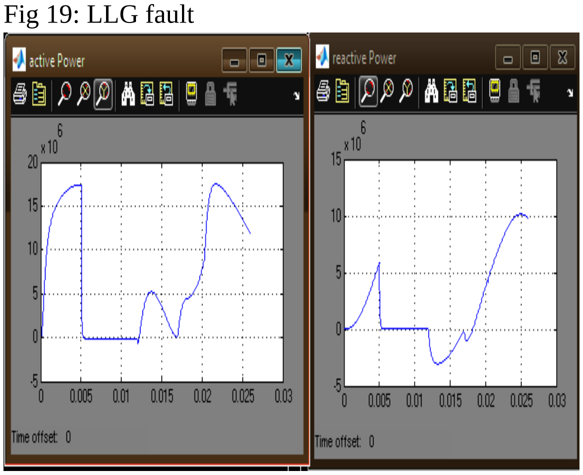

Fig 20: LLG fault

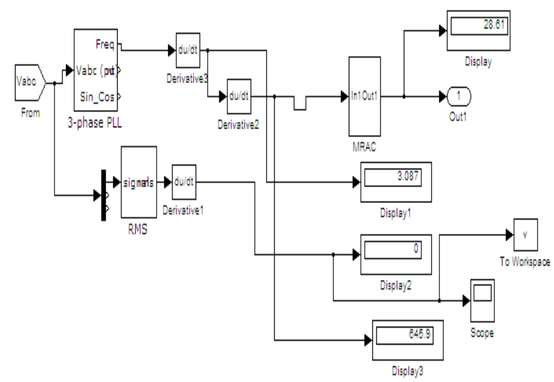

Fig 21: With adaptive controller

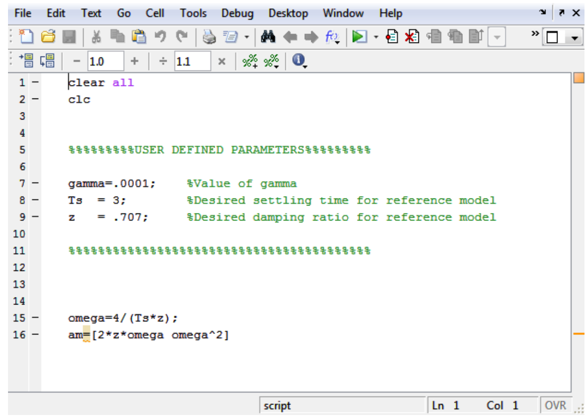

Fig 22: M-file program

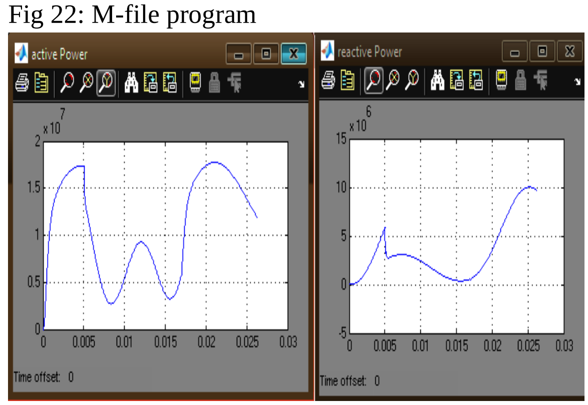

Fig 23: LG fault

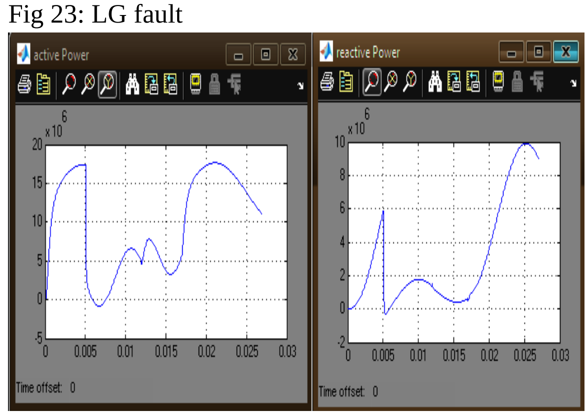

Fig 24: LLG fault

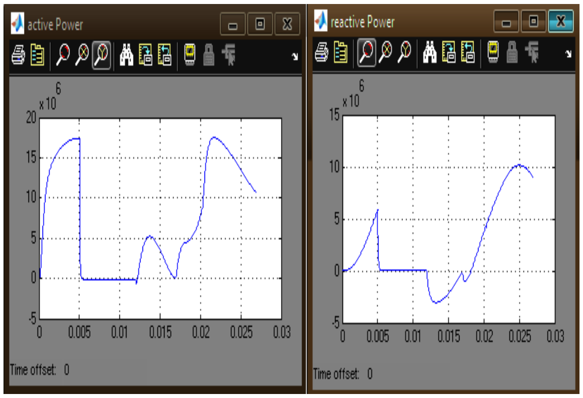

Fig 25: LLLG fault

Table 3: Comparison table of power variation in fault period i.e between 0.05 to 0.1 sec

Without DG and different controllers	Active power			Reactive power		
	LG	LLG	LLLG	LG	LLG	LLLG
PID controller	0.5	3.5	2.5	2.2	1.3	-1.25
FLC controller	0.6	3.6	2.5	1.7	0.9	-1.3
Adaptive controller	3.25	3.65	2.5	1.5	0.95	-1.6

Table 4: Comparison table of power variation in fault period i.e between 0.05 to 0.1 sec

With DG and different controllers	Active power			Reactive power		
	LG	LLG	LLLG	LG	LLG	LLLG
PID controller	0.2	3.5	2.56	2.22	1.13	-0.25
FLC controller	0.45	3.45	2.25	1.71	0.8	-1.1
Adaptive controller	3.15	3.5	2.51	1.55	0.75	-1.4

CONLUSIONS

DEs with power electronic interfaces have the ability of dynamic reactive power support, which can benefit the system's reliability and safety. This dissertation explores how to use DEs for voltage regulation from the "system" point of view. The importance of appropriate controller parameters in voltage regulation is emphasized and challenges in setting these parameters are discussed in the case of a single voltage-regulating DE as well as in the case of multiple voltage-regulating DEs. An adaptive voltage control approach has been proposed to dynamically modify control parameters to respond to system changes. The corresponding formulation of the dynamic control parameters is derived in both the case of the single voltage-regulating DE and the case of multiple voltage-regulating DEs. In the case of multiple DEs, a high-end solution with the requirement of communication among the Des and a low-end solution without the requirement of communication are both proposed, considering the availability of communication systems. Conclusions from the work can be summarized as:

Proportional-integral (PI) control parameters are critical to the stability of the voltage regulation with the DEs. Incorrect parameter settings may cause inefficient (slow response), oscillatory, or worse, unstable responses that can lead to system instability.

Many factors, including network structures, line parameters, loads, and the DE voltage sources, affect the appropriate range of the PI control parameters. It is not feasible for utility engineers to use a trial-and-error method to identify suitable parameters in a case-by-case study. In the case of multiple DEs regulating voltages, one DE's regulation is also affected by the other DE's regulation behavior. The voltage correction of the other DEs may result in excessive compensation at one DE's terminal bus. In this case, the flat reference voltage as an indication of injecting or absorbing reactive power fails to provide a timely regulation direction signal and overshoot of voltage is inevitable if with fixed gains. Hence, an adaptive approach to dynamically set controller parameters is preferable. The protection of DG also includes the type of transformer protection at the utility end. By considering different connections, it was observed that star grounded – delta connection and delta-delta connection have more distortions than compared to other connections.

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