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# Adaptive protection scheme for smart microgrid with electronically coupled distributed generations

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**Abstract** This paper aims at modelling an electronically coupled distributed energy resource with an adaptive protection scheme. The electronically coupled distributed energy resource is a microgrid framework formed by coupling the renewable energy source electronically. Further, the proposed adaptive protection scheme provides a suitable protection to the microgrid for various fault conditions irrespective of the operating mode of the microgrid: namely, grid connected mode and islanded mode. The outstanding aspect of the developed adaptive protection scheme is that it monitors the microgrid and instantly updates relay fault current according to the variations that occur in the system. The proposed adaptive protection scheme also employs auto reclosures, through which the proposed adaptive protection scheme recovers faster from the fault and thereby increases the consistency of the microgrid. The effectiveness of the proposed adaptive protection is studied through the time domain simulations carried out in the PSCAD\EMTDC software environment.


## 1. Introduction

Energy crisis is one of the most important and crucial problems faced by the world in the present decades. Conventional resources that are used for energy production cause environmental pollution and their severe consequences affect the humans in their day-to-day life. To tackle this problem, the energy sector has started to generate its energy requirement through the Renewable Energy Sources (RES) rather than the conventional fossil fuel based energy generation. This type of RES is commonly called as Distributed Generation (DG) or Dispersed Generation [1]. The combination of DGs and local loads with or without the support from the utility grid is called as "Microgrid" [2]. The formation of microgrid reduces the overall operational burden of the utility grid.

Consequently, the generation of bulk power is possible through microgrid, i.e., multiple modules of independent sources rather than a single concentrated power plant. The DG systems are coupled to microgrid by means of electronic devices to form an Electronically Coupled Distributed Energy Resources (EC-DERs) [3].

The microgrid performs independently to maintain overall reliability and stability of the grid [4]. Furthermore, the behaviour of the microgrid is so dynamic, because coupling and shedding of distributed generators or load may take place at any time in the microgrid [5]. On every occasion of such changes, microgrid behaves erroneously such as generating

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power, sharing the load, and providing protection and control strategies [6]. In order to operate normally, microgrid should adapt to the network parameters [7,8]. Moreover, to solve such situation, the microgrid requires an intelligent administrative system for the entire network to give order for the relay in all branches of the network [9,10]. Consequently, an innovative protection system is required for secured operation of the microgrid [11]. In this regard, several approaches have been discussed for the protective scheme of EC-DER. In an approach, over-current based protection strategy is implemented for rotational Electronically Coupled Distributed Generation (EC-DG) in microgrid [12–14]. This system does not require modified protections relays and hence, is more economical. But, it provides ineffective protection for islanded mode of operation. In another approach, symmetrical component based over-current relay has been developed exclusively for the EC-DG based microgrid operation in islanded mode [15,16]. It provides an excellent response to three phase faults. But, frequent single phase tripping occurs in the system. Later, differential current based protection strategy has been developed for protecting EC-DG connected microgrid [17–19]. This protection strategy can operate in both grid connected mode and islanded mode. Further, this protection system can detect the low impedance fault. But, this protection system does not operate effectively when the microgrid is connected with unbalanced loads [20]. To overcome the existing problems a new approach has been proposed by making modification in the protection scheme.

This paper proposes an adaptive protection scheme for microgrids. The proposed protective scheme uses microprocessor-based over current relays. Furthermore, the significant character of the protection scheme is that it acts independently during the magnitudes of fault current and can act in the both grid connected mode and islanded mode. It also increases the reliability of the microgrid by enabling auto reclosure for temporary faults. Also, the proposed system can detect low impedance fault and it is designed in such a way that the power can flow from source to load in a single direction. Hence, this proposed low cost and simple protection schemes can be utilized for enhancing the power system protection. The effectiveness of the proposed adaptive protection is demonstrated through the simulation study carried out in the PSCAD\EMTDC software environment and the results obtained are compared with the conventional protection scheme. The proposed protection scheme provides adequate protection to the microgrid during grid connected mode and islanded mode of operations, and also improves the reliability of the microgrid.

The paper is organized as follows: Development of electronically coupled distributed generation based microgrid is discussed in Section 2. The development of the proposed protection strategy is prescribed in Section 3. The developments of the proposed adaptive protection relay and the test system are given in Section 4. The results and comparative analysis are given in Section 5.

## 2. Development of EC-DER based microgrid

The scope of this paper was to establish the adaptive protective scheme for EC-DGR based microgrid. Hence, the Electronic Coupling (EC) is modelled using power electronic converters followed by the renewable energy resources such as wind, solar, fuel cell and battery energy storage as shown in Fig. 1. The EC pumps the power generated by the DG into the microgrid with the help of power electronic converters.

### 2.1. Modelling the inverter systems

The control strategy for the inverters in the microgrid is selected based on the mode of operation. Both these modes require different functions to be performed by the control strategy. In grid connected mode, the main function to be performed by the inverter is to control the real and reactive power flow. In the islanded mode of operation, microgrid voltage and frequency regulation are the main functions to be performed. The simplified control scheme is shown in Fig. 2. The control scheme in the grid connected mode is commonly called as the current-control mode. In this mode the real and reactive power of the EC-DG is controlled. First, the control scheme directly controls Voltage Source Converter (VSC) output current, which in turn is used to control the real and reactive power by varying the phase angle and the magnitude of the current with respect to the VSC terminal voltage [21]. The unique feature of this control mode is that it automatically acquires the overload protection, since the current regulation is employed in this strategy.

Initially, the voltage and current in each phase are measured using the CT and PT. By means of *abc* to *dq*0 transformation and PLL block, the measured $I_{abc}$ and $V_{abc}$ are converted to give $I_d - I_q$ component. Out of two components, the *d*-axis component is used to control the real power and the *q*-axis component is used to control the reactive power. The obtained $d{-}q$ axis current component is compared with the desired set point value of the reference current vector determined from the extractor block using the measured real and reactive power. The obtained error value is given as input to the PI based current controller. The current controller processes the error value and gives reference voltage vectors in *d*–*q* orientation frame. This voltage vectors in *d*–*q* are given as input to the voltage controller. The obtained *d*–*q* references are transformed into stationary reference frame using *dq*0 to *abc* transformation. Therefore, the obtained stationary reference frame is used by the Space Vector Pulse Width Modulation (SVPWM) to generate switching signals for grid coupling VSC [22]. Further, additional RLC filter is used in between converter and transformer for filtering purpose, where $R = 0.0005\,\Omega$, $L = 0.5$ mH and $C = 100\,\mu$F. In the Islanded mode of operation, in addition to the real and reactive power control, the voltage and frequency regulation are also taken into consideration for controlling the inverter. In grid connected mode the need for voltage and frequency regulation is not much emphasized because the host utility grid supports voltage and frequency regulation of the microgrid. The voltage and frequency regulation can be accomplished by encoding the significance of the change in the voltage and frequency in the *d*–*q* reference current vector. The rated voltage and frequency are kept as set point values and then compared with the current value of the EC-DGs. The obtained error signal in *d*–*q* reference frame is passed through a PI controller with suitable gains. The frequency component and voltage component are added to the real and reactive power components respectively, which have already been generated in the reference current block. Hence, the rest of the operation is the same as that like