ISSN 2229-5518

Coordination Issues in Over Current Relays due to Wind Farm Penetration

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Abstract— Power demand is going on increasing day by day around the world. There are many solution strategies to avoid the sustaining energy shortage. The distributed generation is one of the remedial measures taken by many countries. The integration of intermittent distributed generation sources causes many problems in protection level including the malfunction of over current relays. The coordination of the over current relays is affected by the penetration level of the DG sources including wind farms. In this paper a typical wind farm is taken as the case study and found that coordination in the over current relay is affected by the variation in the penetration of wind farm output. The solution strategy proposed for the miscoordination is adaptive relaying and an algorithm developed for it.

Index Terms— Adaptive Relaying, Electrical Transient Analysis Program, Distributed Generation, Multiagent System, Over Current Relay, Relay Coordination, Wind Generator.

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1 Introduction

DISTRIBUTED Generation sources including renewable energy sources is one of the solution for the sustaining energy shortage. Among the various renewable energy sources the generation of power from wind farms is growing at faster rate [1]. There are various protection issues by the addition of wind farm to the existing grid. It includes increase in fault current, problems in protection coordination, blinding of protection, islanding, sympathetic tripping etc. [2-3].

The electrical demand has been continuously increasing in most electric utilities. There will be short and long-term impact on the extension of power generation, transmission line, change in power network topology, power flows, fault level etc on protection system. The main reason for these changes is due to the addition of renewable sources like wind power, solar power etc. The concept of adaptive power system relaying is introduced to meet these problems. The setting of protective relay may need to be adjusted automatically its characteristics on-line to suit any change in power system conditions. The protective relays are pre-designed to respond to faults or any abnormal conditions. Their setting is always fixed at a predesigned value. This setting cannot ensure that the predesigned protection system will be appropriate for all power system including the addition of DG sources. This can be achieved by microprocessor based relays in small power systems. In large-scale power transmission network, communication among a control center and these protective devices is necessary and it can be achieved by agent technology. The following are the characteristics of agent technology autonomy, cooperation, intelligence and adaptation.

In various literatures different methods are proposed for adaptive relaying. [4-6]. A new development in adaptive relaying technique is multiagent system in which software knowledge is given to different elements like circuit breaker, relays, current transformer etc [7-8]. In the existing literatures, the adaptive relaying technique applied to a particular system is not applicable to other systems or it will not take care of future additions of wind sources or modifications. In this paper a generalized algorithm for adaptive relaying is proposed to avoid the coordination problems in the over current relays.

2 Relay Coordination

Overcurrent relays are protective relay that operates when current exceeds its preset value. The overcurrent relays are usually placed at the secondary side of the current transformer. The operating time of the overcurrent relay can vary due to relay type, time-dial setting (TDS) and magnitude of fault currents. The ANSI device number for over current relay is 51. The operating time of the over current relays according to IEC standard is

$$T = \frac{\beta X TDS}{PSM^{\alpha} - 1} \quad (1)$$

$$PSM = \frac{I_{act}}{I_{pickup}} \quad (2)$$

Where α and β are arbitrary constant

PSM is the plug setting multiplier

$I_{pick\,up}$ is the pickup current of the relay

I_{act} is the actual current seen by the relay

During faulty conditions, the operations of relays are in such a way that the minimum area is to be isolated. It seems that the presence of distributed generation affect the sequence of operation of relays. The mal-operation of over current relays may cause isolation of more areas or does not isolate, affecting the reliability of the system and it is termed as coordination problem. The software used for the simulation studies is Electrical Transient Analysis Program.

3 IEEE Five Bus System

The figure given below (Fig.1) is IEEE 5 bus system, which has got five buses, six transmission lines, two generator buses (200 MW) and three load buses (Fig.1). A wind generator of 10

MW is connected to bus number 4. The disadvantage of wind farm generation is its varying output. Based on the availability of the wind generator may or may not put into the service.

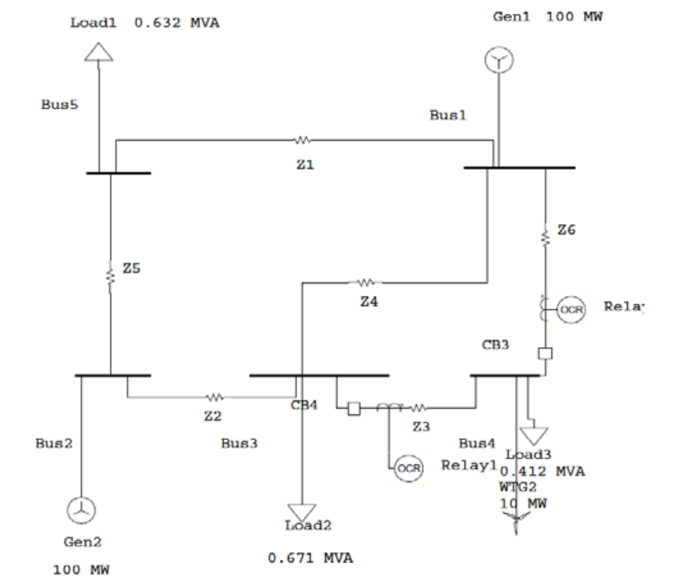

Fig. 1 IEEE Five Bus System with Wind Generator.

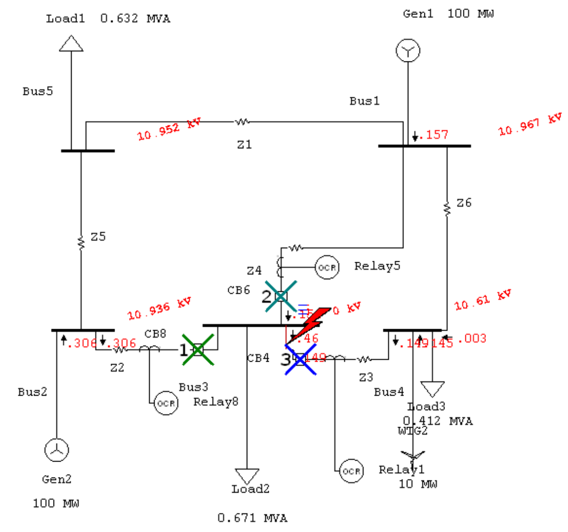

Fig. 2 Normal operation of Relays.

In the following figure (Fig.2), a three phase short circuit fault is inserted in bus 3. In normal operation the fault should be isolated from the surrounding regions or it is avoided to transmit to more regions. All the over current senses the fault current and trip.

In Figure 3 the wind generator is made out of service due to less or no wind. When the wind speed is below cut in speed the wind generator produces zero power output. The three phase short circuit fault is inserted is inserted in bus number 3. The over current relay inserted in the line between the bus number 3 and 4 will not operate and the fault is transmitted to more areas.

The wind generators put in sevice cannot be predicted. Based on the availibily of wind, the wind generators may or may not be put in service.

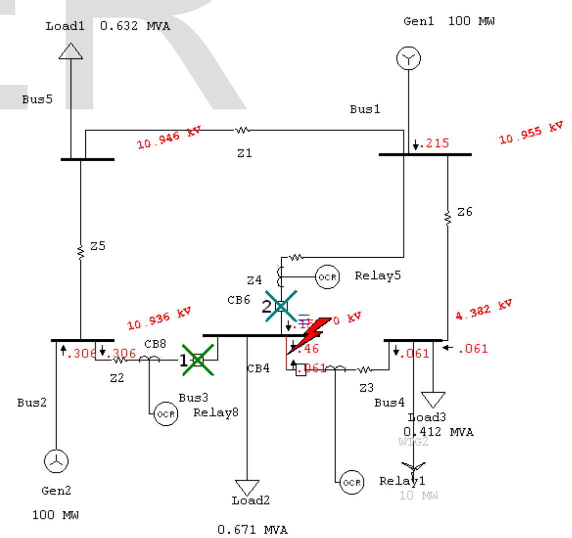

Fig. 3 Maloperation of Relays

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4 Case Study

Kanjikode wind farm situated near Palakkad 220/110kV substation is taken as case study. It has total nine units of Vestas V27 225kW wind turbines. The turbine has a rotor diame-

ISSN 2229-5518

ter of 27m and has 43rpm of nominal speed. The cut-in speed of wind is 3.5m/s and the cut-out speed is 25m/s. The turbine uses asynchronous generator technology i.e. a Squirrel cage induction generator (SCIG) which has a two set of winding of 6 pole and 8 pole each for 1000 rpm and 750 rpm synchronous speed respectively. The squirrel cage generator output is at 400V, 50Hz. Each 3 units are connected to 1 MVA, 400V/22kV, 50Hz transformer bank which is then connected to 25MVA 110kV/22kV substation transformer. There are various protection issues associated with the integration of wind farm at the substation integrating wind farm to the grid. The fault level of various buses in the substation is varied based on the availability of DG units.

Relay setting done for grids with all DGs are present is not enough, when some DG's are not present. In figure 4 the sequence of operation of relays are correct, isolating the minimum area of the system and provides maximum security. In figure 5 first three generators are not isolated from the fault. Relay is not able to identify the changes in DG capacity and mis-operates.

The above prolems in relay operation can be solved by adaptive relaying technique. The different alogorithms based on differential evolutuion, linear programming, bees colony optimization, fire fly optimization, genetic algorithm, multiagent system etc are given in papers [9]-[15]

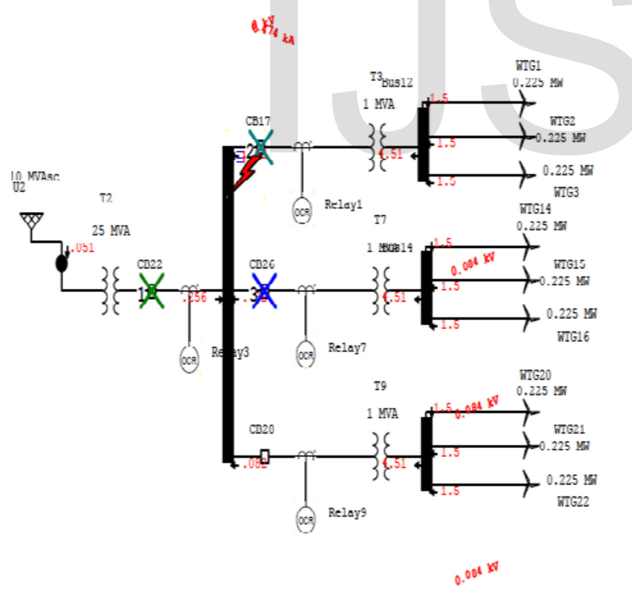

Fig. 4 Operation of over current relays when all DG's running at the rated conditions

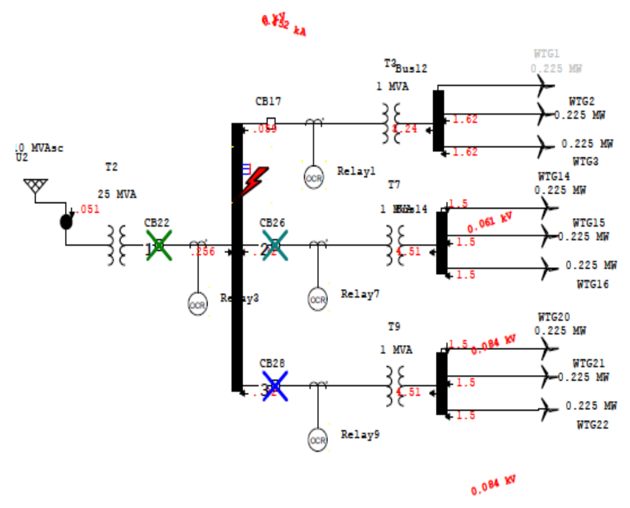

Fig. 5 Operation of over current relays when all DG's running not at the rated conditions

5 Adaptive Relaying

The solution method suggested is adaptive over current relay in which relay has to adapt to the changing environment. An algorithm is proposed to avoid the coordination problem and the same is tested in the case system. The flow chart for the same is shown in the figure 6. Adaptive relaying technique continuously monitors the status of the entire system through load flow analysis, collecting information from the breaker status etc. The optimal setting for the relay which is most appropriate at that time has to be found out and it is passed to the relay The various algorithms for adaptive relaying is proposed in the papers [7]-[8].

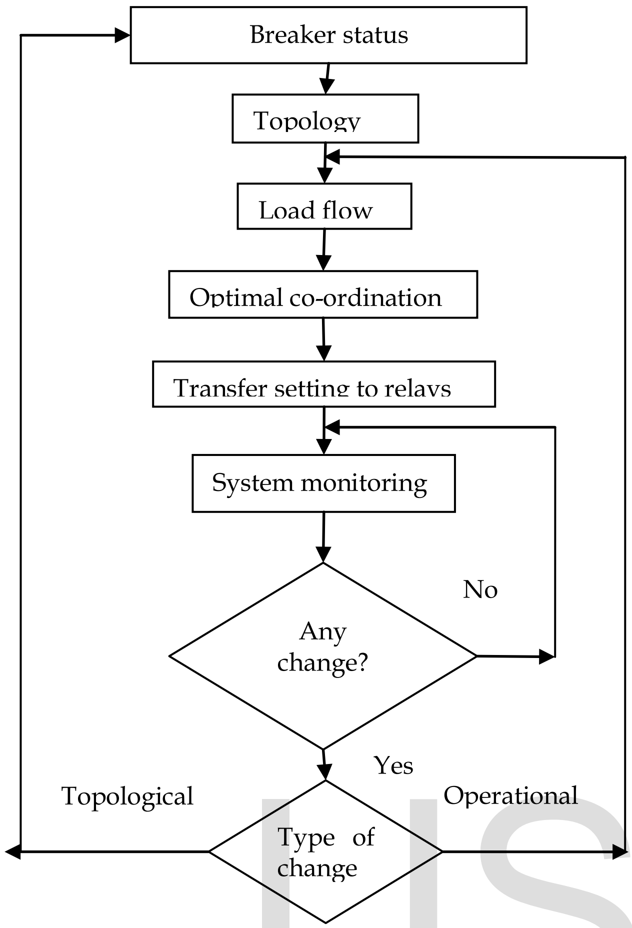

Fig. 6 Flow Chart for Adaptive Relaying

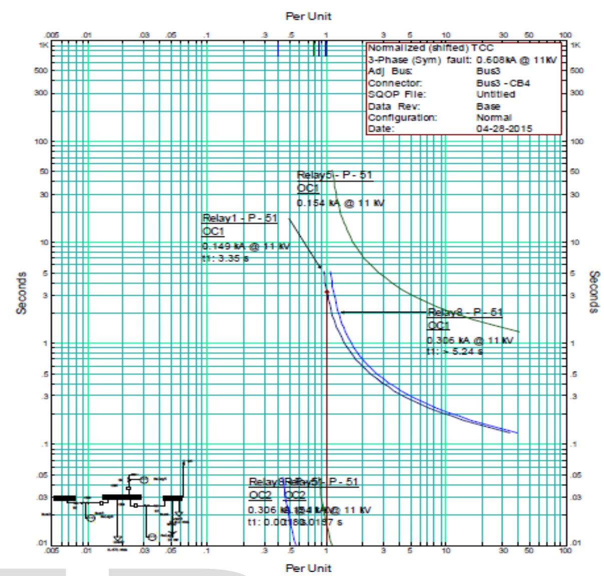

Fig. 7 Relay characterictics f when the DG is running at rated condition

Adaptive relaying includes changes in relay settings or relay characteristics in online manner according to environmental changes. The changes include generator outage, line outage or load variations. In the current scenario more and more DG's are connecting to the existing grid. The addition of distributed generation also requires some variations in the relay setting. Adaptive relaying improves relaying reliability and power system security. Adaptive relaying is defined as an on-line activity that modifies the preferred protective response to a change in system conditions or requirements which is automatic, but can include necessary human intervention. Adaptive relay is defined as the relay that can have its settings or characteristics changed on-line in a timely manner by means of externally generated signals or control action. The following figures shows the time current characteristics of over current relays connected in IEEE five bus system. Figure 8 shows the time current characteristics for normal operation of over current relay. From the time current characteristics it is noted that the relay no.3 is not operated, when DG is put out of service. The modified characterstics to avoid mal operation is shown in figure 10.

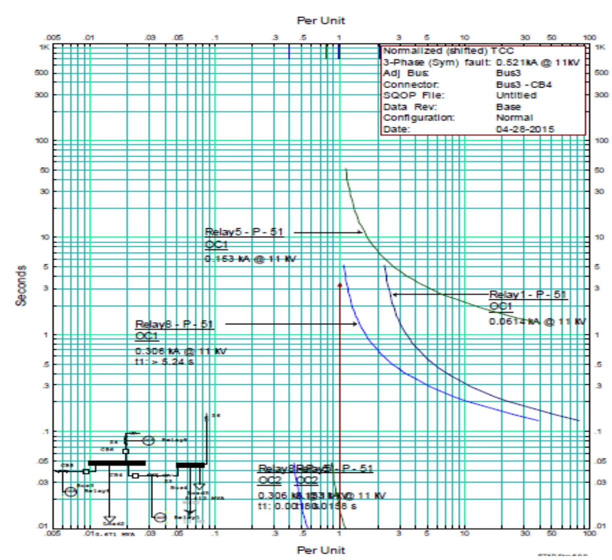

Fig. 8 Relay characterictics when the DG of 10 MW is out of service

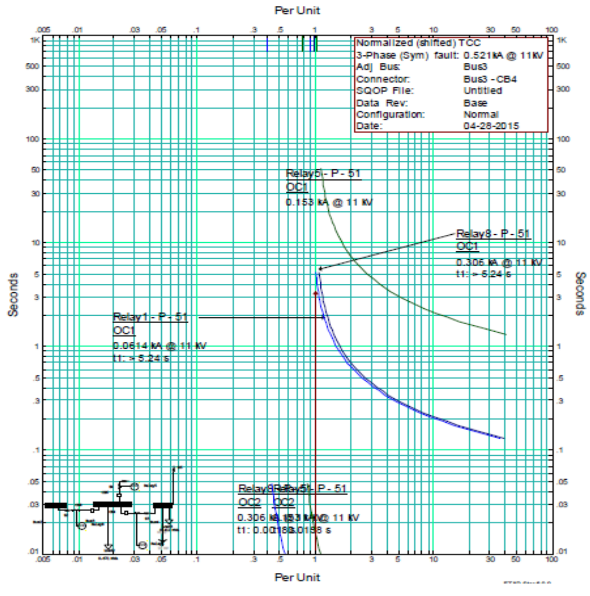

Fig. 9 Modified Relay characteristics according to DG penetration

6 Conclusion

Relay coordination is a major factor to be considered by the addition of renewable sources. In this paper a typical substation by which the wind farm is connected to the grid is taken and found that the over current relays may or may not operate by the variation in power output. The solution strategy is adaptive relaying and an algorithm for the same is presented.

Acknowledgment

The authors gratefully acknowledge the contributions Kerala State Electricity Board for the data collection.

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