

PROTECTION OF SCIG BASED WIND ENERGY CONVERSION SYSTEM SUPPLYING LOAD USING OVERCURRENT RELAY

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Abstract

Electrical load demand that are met through renewable energy generations are increasing nowadays. Wind energy conversion system (WECS) is one of the earliest methods and also efficient way for electricity generation. It has become very important to protect these wind farms from various faults for efficient power generation. In this paper, a single wind turbine with squirrel cage induction generator (SCIG) supplying a three phase load with different faults is simulated and using the proposed inverse time overcurrent relay (OCR). These faults have been nullified at the prescribed time interval, system is simulated in PSCAD/EMTDC simulation software. The current through all the three phases is observed during and after the fault instances for designing system in real time.

Key Words: Wind Energy Conversion System, SCIG, Overcurrent relay, IEC standards

1 INTRODUCTION

Wind energy conversion system is employing an important role in producing electrical energy as the need for green energy requirement is increasing. A wind turbine coupled with a generator is used to generate electricity is mostly used as distribution generation (DG) system [1]. But, due to various reasons constant electricity generation is being affected. There are two factors considered as the disturbances, one is the physical disturbances it may be due to birds and natural disasters. And the other is the disturbances occurs in power system, the main disturbance considered is the faults that occurs at various places. These faults occur for numerous reasons which has to be nullified or cleared within the time limit otherwise the devices in the system is stressed or damaged. For this reason the system has to be protected with good protective scheme.

In [2] over current relays which employs IEC standards for the protection of wind farm with three wind turbine is explained using Matlab/simulink. Paper [5] uses user defined characteristics for inverse time overcurrent relay implemented in meshed distribution network for IEEE 30 bus for synchronous based DGs. [6] Proposes a time-current-voltage tripping characteristic for directional overcurrent relays in meshed distribution system to reduce overall which reduces the overall relay operating time. [8] Proposes coordination for overcurrent relays implemented in distribution generation system for the protection of the power constituents during fault occurrence. [9] Proposes optimal overcurrent relay coordination in protection system overview as well as artificial intelligence and nature inspire algorithm also used in overcurrent protection. The proposed system uses inverse time overcurrent relay which works based on the integration function. The input current is integrated as a function of current, when the current exceeds the preset value then it sends a signal from relay to circuit breaker for tripping. Using overcurrent relay makes it simple to eliminate the periods when current through rises a small percentage from its actual value during loading condition. The model is simulated and results are compared for the designing purpose.

2 NETWORK MODELING

For the implementation of OCRs in wind system, a simple model consisting of single wind turbine supplying a load through transmission line using SCIG which is a constant speed generator. Represented in the figure (1).

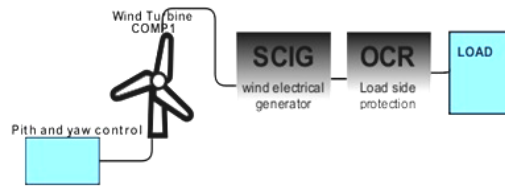


Fig 1. Block representation of proposed system configuration

A. Wind turbine

The device that converts kinetic energy present in wind to mechanical energy is called as wind turbine. The relation between wind and mechanical power is given by equation (1).

$$P_t = \frac{1}{2} \rho_t A_r V_w^3 C_p \quad (1)$$

Where P_t the power is available from the wind turbine, A_r is the area of rotor blades, V_w^3 is the input wind speed to the wind turbine, C_p is the power coefficient of that particular wind turbine used. Tip speed ratio λ is given by the ratio of ω_m angular speed of the machine and radius of the rotor R to the speed of the wind V_w .

$$\lambda = \frac{\omega_m R}{V_w} \quad (2)$$

B. Wind Generator modeling

Wind turbine generators can be divided into fixed speed and variable speed wind turbine generators. In this paper, fixed speed squirrel cage induction generator (SCIG) is used to supply load. Standard model of induction generator is available in PSCAD/EMTDC simulation software.

C. Modeling of inverse time OCR in PSCAD

In PSCAD, an inverse time OCR block is present. The input current is integrated as a function of current, the output signal is

the trip signal to the breaker, when the current exceeds the preset value then it issues a high signal. The pick up value and time delay setting is characterized based on the operation of the system where the tipping constants of the integrator are set.

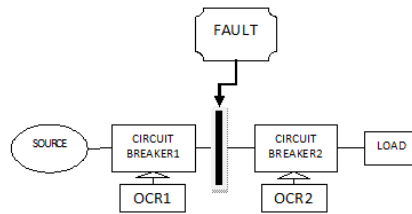


Fig 2. OCR implementation block representation

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Figure 2 represents, the implementation of OCRs for the network consisting of wind farm. Inverse time OCRs trips when the current exceeds its pick-up value, the operating time also decreases during with increase in current level. Different characteristics of OCRs based upon IEC standards are tabulated in table (1).

Table 1. Characteristics of OCRs Based on

Type of OCR	Operation time
Normal inverse	$T = \frac{0.14 * TSM}{\left(\frac{I}{I_{pickup}}\right)^{0.02} - 1}$
Very inverse	$T = \frac{13.5 * TSM}{\left(\frac{I}{I_{pickup}}\right)^1 - 1}$
Extremely inverse	$T = \frac{80 * TSM}{\left(\frac{I}{I_{pickup}}\right)^2 - 1}$
Long time inverse	$T = \frac{120 * TSM}{\left(\frac{I}{I_{pickup}}\right)^1 - 1}$

In OCR there are two settings they are Plug Setting Multiplier (PSM) and Time Setting Multiplier (TSM). From [9] for phase to phase fault PSM is varied from 50% to 200% in the steps of 25% and for phase to ground fault variation from 10% to 40% in step

of 10%. TSM ranges between 0.05 and 1 second. The OCR here used has setting based on IEC standards and pick up current value given as 30 Amperes.

3 SIMULATION RESULTS FOR OCR SUPPLING THREE PHASE LOAD

The system described above is modeled in PSCAD simulation software and various faults have been made in bus near the load. Due to this fault, current increases breakers near the bus will operate in response to the signal from the inverse time OCRs. Overcurrent relay send this signal to close the breaker in that instant. The induction generator operated at 230 kV at 60 Hz frequency. It supplies a three phase resistive load of 2.5 MW. Symmetrical and asymmetrical faults are created near the load bus and results are simulated. Breaker 1 and breaker 2 operated with the respective OCR1 and OCR2 as shown in the block diagram (). At normal load condition current flow is about 6.6 amps. A single line to ground fault at phase A for 2 seconds is created and the current is raised to 2310.68 amps. The breakers 1 and 2 are tripped at 2.5 seconds and 4.51 seconds respectively, after the fault is cleared at 4.5 seconds, the breakers are reclosed at 3.5 and 4.51 seconds. The results are simulated and graph is shown in the figure (3).

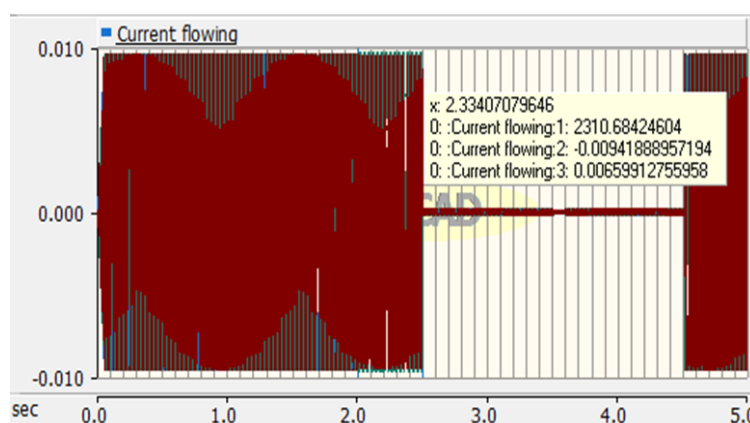


Fig 3. Single line to ground fault current waveform

Line to line fault is created between phase A and phase B, current raises to 10525.94703 and -10525.94703 Amperes in phase A and B respectively. Output graph is simulated and represented in figure (4) as tripping of breaker operated in time.

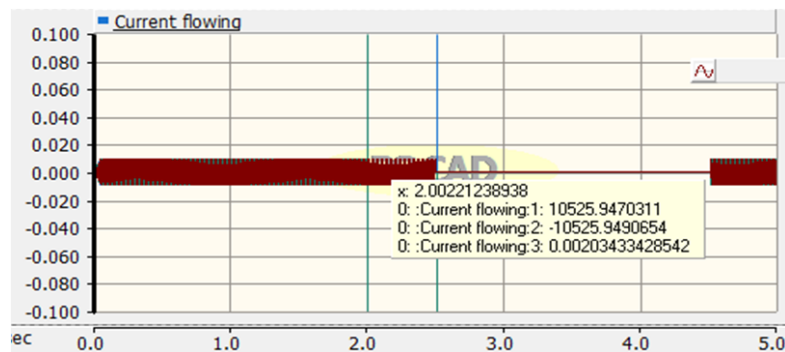


Fig 4. Line to Line fault current waveform

Double line to ground fault is created near load (fig 5). Current falls to 2.2 amps in phase A, and rises to 6504.8 amperes in phase B and -9155.4594 amperes in phase C. Breakers operated at 2.5 and 4.51 respectively and reclosed at 3.5 and 4.51. Then the load current is restored to its nominal value.

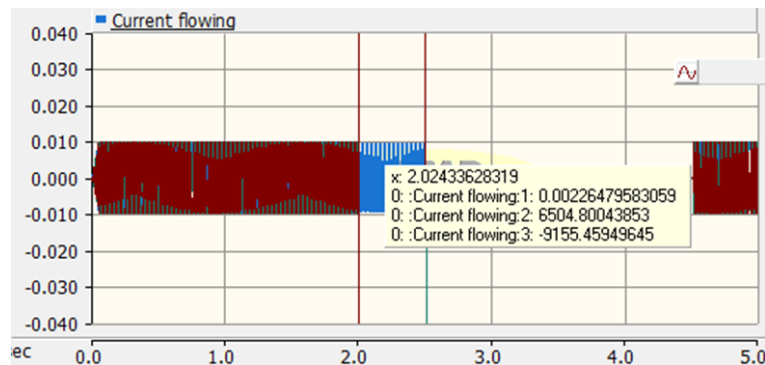


Fig 5. Double line to ground fault current waveform

A very severe fault which is three phase to ground fault is created for 2 seconds, the current raises of about 3797.4711 amps, 9814.0513 amps and -13611.5225 amps for the respective phase A, phase B and phase C (fig 6). Breaker 1&2 are operated to protect the wind turbine and load from high current.

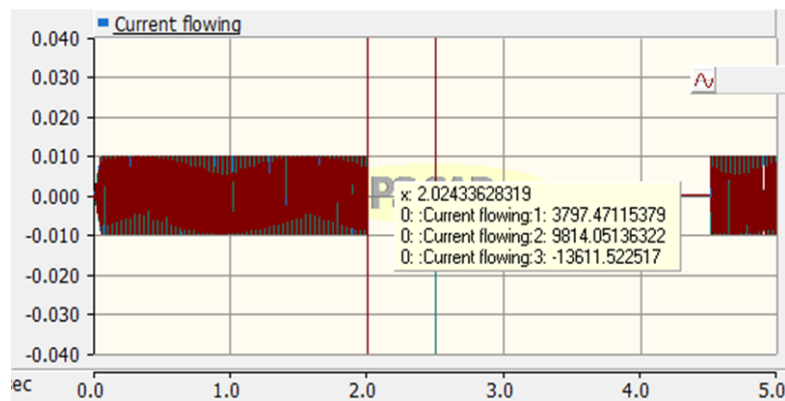


Fig 6. Three phase fault current waveform

The faults that has been created and reclosed and the current intensities are all tabulated in table (2) for comparison over various faults.

Table 2. Comparison of characteristics for different fault for three phase load

Type of fault	Fault duration (sec)	Breaker trip time (sec)	Breaker reclose time (sec)	Fault currents (sec)
Single line to ground fault	2.5	B2 -2.5 B1 -3.5	B2 - 3.6 B1 -4.51	$I_a=2310.6$ $I_b=-0.009$ $I_c=0.0065$
Line to line fault	2.5	B2 -2.5 B1 -3.5	B2 - 3.6 B1 -4.51	$I_a=10525.9$ $I_b=-10525.9$ $I_c=0.002034$
Double line to ground fault	2.5	B2 -2.5 B1 -3.5	B2 - 3.6 B1 -4.51	$I_a=0.002264$ $I_b=6504.80$ $I_c=-9155.45$
Three phase fault	2.5	B2 -2.5 B1 -3.5	B2 - 3.6 B1 -4.51	$I_a=3797.471$ $I_b=9814.05$ $I_c=-13611.5$

4 Conclusion

Protection of wind turbine has become very important due to its growing implementation in vast areas. The overcurrent relay protects the system from fault current with the IEC standards implemented over relay settings. Though the fault instant cannot be controlled, the current magnitude can be limited to protect the system for a brief period of time. The results are tabulated for consideration of design a system in real time and with the graph generated during fault instance stability response can also be obtained.

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