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Wireless Aided Protection for 110 KV Transmission Line to Improve the System Stability

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ABSTRACT**:** Whenever the fault occurs in the power system, the faulty element must be isolated from the power system as soon as possible to reduce the fault current flow through the system. If the system voltage is higher, the severity due to fault is more. It leads to reduce the system stability, life period of equipment, performance of the system, power quality of the system. No part of power system remains without protection and also to avoid maloperation, the transmission line is segregated as zone1, zone2 and zone3. The fault clearing time is the sum of relay time and breaker time. The breaker time can't reduce because it is almost 2-3 cycles. The relay time is instantaneous for zone1, 400 milliseconds time delay for zone2, 1 second time delay for zone3. So the relay time must be reduced to minimize the fault current. The carrier aided protection is used to reduce the relay time in 230 KV system and above transmission line to reduce the fault current. But in 110 KV and below transmission line, the carrier aided protection is not utilized due to high cost. So wireless aided protection (WAP) is introduced in 110 KV system and below to reduce the fault current. Hence the stability, performance and quality of the 110 KV system are improved due to minimization of fault current. If it is used in 230 KV system and above instead of carrier aided protection, it reduces the cost of protection.

KEYWORDS: Power System, Fault Current, Protection, Wireless aided Protection (WAP)

I. INTRODUCTION

Most of the transmission lines are overhead lines. In which there are two types of fault. One is open circuit fault and another one is short circuit fault. Open circuit fault means one or two phase conductors open. It is occurred due to heavy wind, loose and decoupling of line etc.The short circuit fault is occurred due to insulation failure, collision of vehicle, bird fault, tree falling etc. The weakening of insulation due to one or more of the following factors such as ageing, temperature, rain, hail, snow, chemical pollution, foreign objects. Those faults, which involve only one of the phase conductor and ground is called ground faults. Faults involving two or more phase conductors with or without ground are called phase faults. In which 85 % of the faults are single line to ground fault, 8 % of the faults are double lines short circuit fault, 5 % of the faults are double lines to ground fault, 2 % of the faults are three phase fault[2].

If any fault occurs in a power system, the faulty element must be isolated from the power system as soon as possible to maintain the power system stability and also to safe guard the equipment. The fault current may be more than ten times of the normal full-load current. If these fault currents persist even for a short time, they will cause extensive damage to the equipment that carries these currents. Over-currents, in general, cause overheating and attendant danger of fire. Overheating also causes deterioration of the insulation, thus weakening it further [1]. Not so apparent is the mechanical damage due to excessive mechanical forces developed during an over-current. Transformers are known to have suffered mechanical damage to their windings, due to faults. This is due to the fact that any two current-carrying conductors experience a force. This force goes out of bounds during faults, causing mechanical distortion and damage.

Further, in an interconnected power system, there is another dimension to the effect of faults. The generators in an interconnected power system must operate in synchronism at all instants. The electrical power output from an

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alternator near the fault drops sharply. However the mechanical power input remains substantially constant at its pre-fault value. This causes the alternator to accelerate. The rotor angle δ starts increasing. Thus, the alternators start swinging with respect to each other. If the swing goes out of control, the alternators will have to be tripped out. Thus in an interconnected power system, the system stability is at stake. Therefore the faults need to be isolated as selectively and as speedily as possible [2].

II. EXISTING METHOD

OVER CURRENT PROTECTION

The over current relay is operated by sensing the current flow through the feeder. The current flow through the feeder is measured by using current transformer which is erected in the feeder itself. If the measured current flow through the feeder exceeds the preset value of the over current relay, then the relay gives trip command to the circuit breaker. Over-current protection is very appealing and attractive because of its inherent simplicity. It is used as a primary protection for low voltage (LV) distribution lines. However, it has some major drawbacks which cause it to mal operate. In LV systems, the mal operation of relays can be tolerated. The only consideration in LV systems is the continuity of supply to the consumers. However, in EHV systems mal operations cannot be tolerated. This is because EHV lines are part of an interconnected grid. Any mal operation on these systems leads to instability of the electric grid. So the distance protection is preferred as main protection and the over current protection is preferred as backup protection in 110 KV transmission line [1]. But in 230 KV systems and above both protections are distance protections.

DISTANCE PROTECTION

The distance protection relay is operated by sensing the voltage at the bus and the current flow through the feeder. For that the potential transformer is erected in the bus to measure the bus voltage. From the measured voltage and current first it calculates the V/I ratio to find the magnitude of Impedance (Z). Then it measures the phase angle between the voltage and current. Based on the relation it takes the directional decision. If the measured angle is lying in first quadrant then the direction is forward. Otherwise reverse. If both the measured impedance is less than the preset impedance value and the direction is in forward direction then it gives trip signal to the circuit breaker to isolate the faulty element from the power system. [1].

If any short circuit fault occurs in the feeder, the current flow through the feeder increases and the bus voltage decreases. Then the measured impedance is reduced below the preset value ($Z_{measured} < Z_{preset}$). Hence the relay gives trip command to the circuit breaker to isolate the fault.

$$Z\ sec = CT\ ratio / VT\ ratio \times Z\ prim$$
$$Z\ sec = (VT\ sec / VT\ prim) \times (CT\ prim / CT\ sec) \times Z\ prim$$

VT prim = Primary voltage of Voltage transformer
VT sec = Secondary voltage of Voltage transformer
CT prim = Primary current of Current transformer
CT sec = Secondary current of Current transformer
$Z_{measured}$ = Measured value of Impedance
Z_{preset} = Preset value of Impedance

This is the line impedance actually seen by relay. It may differ from the calculated value due to the following calculation errors.

a) CTs and VTs measurement errors.
b) The fault resistance recognition due to the effect of load transfer.
c) Zero sequence mutual coupling from parallel lines.
d) The phase impedance of untransposed lines is not equal for all fault loops. The difference between the impedance of different phase-phase loops can be as much as 5-10%.[3]

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To avoid mal operation, the transmission lines are segregated as zone1, zone2 and zone3. For zone1 protection line impedance is limited up to 80% of the line impedance. The impedance setting for zone-2 protection is 100% of line impedance and 50% of the shortest line impedance which is emanating from other end. The impedance setting for zone-3 protection is 100% of line impedance and 50% of the longest line impedance which is emanating from other end.

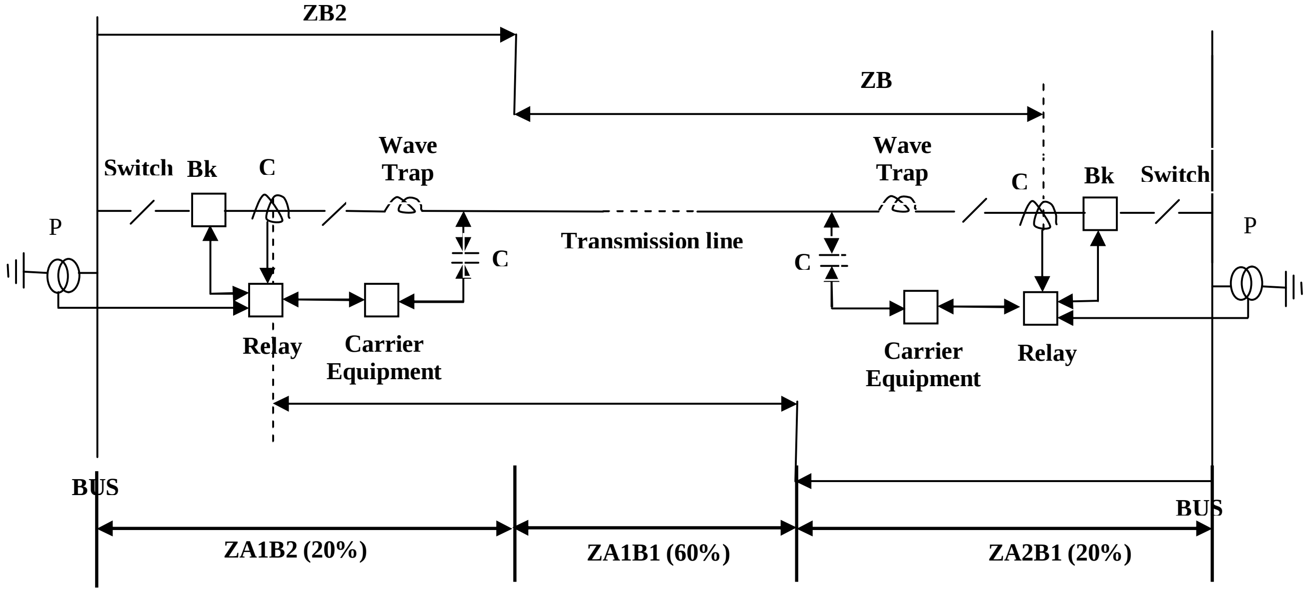

Fig 1 Carrier aided protection

Let us consider the fig 1, the bus A and bus B are interconnected through a feeder. The 80% of line length from bus A is zone1 for the relay A. It is mentioned as ZA1. The remaining 20% of the line length ie. 80% to 100% is zone2 for relay A. It is mentioned as ZA2. The 80% of line length from bus B is zone1 for the relay B. It is mentioned as ZB1. The remaining 20% of the line length ie. 80% to 100% is zone2 for relay B. It is mentioned as ZB2. The 60% of the line in the middle is zone1 for both relays A and B. It is mentioned as ZA1B1. Hence the first 20% of the line from bus A is mentioned as ZA1B2. The last 20% of the line from bus A is mentioned as ZA2B1. If the fault is in zone1, then the time taken by the relay to give the trip command is instantaneous. If the fault is in zone2, then the time taken by the relay to give the trip command is 400 milliseconds.

If any fault is occurred in the region ZA1B1, it is zone1 fault for both ends. Hence both end relays A and B give trip command to the circuit breakers to isolate the fault instantaneously. Suppose if any fault is in ZA2B1, then relay at bus B gives trip command to the circuit breaker instantaneously and the relay at bus A gives trip command to the circuit breaker after 400 milliseconds. Even though the fault is persist, one end isolate the fault instantaneously, the other end feeds the fault current up to 400 milliseconds. So it is to be avoided because it reduces the system stability.

Hence the carrier aided protection is used in 230 KV system and above to isolate the fault from both ends instantaneously. But the carrier aided protection cannot be used in 110 KV system due high cost of carrier equipment.

CARRIER AIDED PROTECTION

In carrier aided protection, wave trap is connected in series and coupling capacitor is connected in parallel with the transmission line. The wave trap acts as low pass filter. It allows the power frequency which has 50Hz and blocks the carrier frequency which has in terms of megahertz. But the coupling capacitor acts as high pass filter. It allows the carrier frequency and blocks the power frequency. Carrier equipment is to be installed in the control room. The relay is interfaced with carrier equipment. The signal can be transmitted to the other end or received from other end through the carrier equipment.

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If any fault is occurred in ZA1B2, the relay at bus A senses the fault and gives the trip command to the circuit breaker instantaneously as well as sends a signal to the other end through carrier equipment. The relay at bus B both senses the fault and receives the carrier signal from other end and it gives the trip signal to the circuit breaker to isolate the faulty element from the power system instantaneously. So the fault current is reduced due to fault clearing time is minimized. Hence the system stability is improved.

AUTO RECLOSURE OPERATION

Carrier aided protection is also utilized for auto reclosure operation. In 230 KV systems and above, each phase has separate breaker with independent operating mechanism. If anyone phase to ground fault occurs in the feeder, the auto reclosure relays which are installed on both ends operate and give the trip command to the faulty phase circuit breaker only to isolate the fault and also it sends a signal to the other end relay through carrier equipment. So the faulty phase circuit breaker on both ends trip instantaneously and close after 200 milliseconds. This time is enough for the de-ionization of air at the fault place. If it is a passing fault, then the breaker stands hold on both ends. If the fault is persist or the fault occurs again within 15 secs then both ends relay give three pole trip commands to the circuit breaker. If the fault occurs in the feeder after 15 secs, then the auto reclosure relay repeat the operation. Hence the 15 secs is called as reclaim time.

The cost of carrier aided equipment is more. Hence it cannot be utilized in 110 KV systems and below. In TNEB nearly thousand 110 KV feeders are in service. Due to the absence of carrier aided protection in 110 KV transmission line, the following drawbacks are occurred.

1. It reduces the stability of the system
2. It reduces the performance of the system
3. It reduces the power quality of the system
4. It reduces the life period of equipment.
5. It twists the rotor shaft in generator.
6. It weakens the insulation of equipment.
7. It damages weaken the equipment
8. Current Transformer saturates

III. PROPOSED METHOD

WIRELESS AIDED PROTECTION

The ZigBee 802.15.4 based wireless aided protection is introduced in 110 KV system to eliminate the relay time and reduces the fault current. For that microcontroller, transmitter and receiver are to be installed on both ends. The microcontroller interfaces with relay, transmitter and receiver as shown figure2.

The receiver continuously monitoring, if any signal receives from other end it is transmitted to the relay through microcontroller. If the microcontroller receives any signal from the relay then the signal is transmitted to the other end using transmitter. The signals are transmitted and received in the form of binary.

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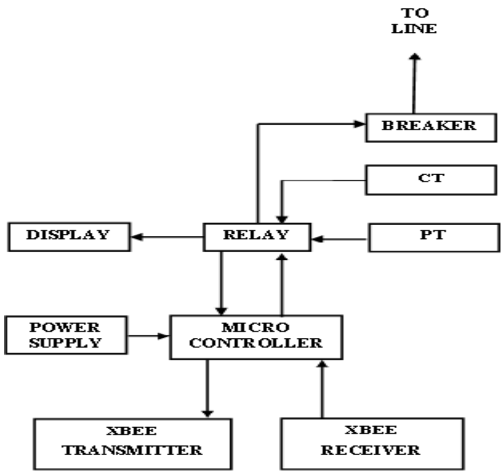

Fig 2 Block Diagram

Let us consider the figure3, if any fault is in ZA1B2 the relay at bus A senses the fault and gives the trip command to the circuit breaker instantaneously as well as sends a signal to the other end through ZigBee based wireless aided protection. The relay at bus B senses the fault and receives the signal from other end as confirmation then the relay at bus B gives trip command to the circuit breaker instantaneously to isolate the faulty element from the power system. If the signal does not receives from other end then the relay at bus B gives the trip signal to the circuit breaker after 400 milliseconds. So the ZigBee based wireless aided protection is used to reduce the fault current by eliminating the relay time.

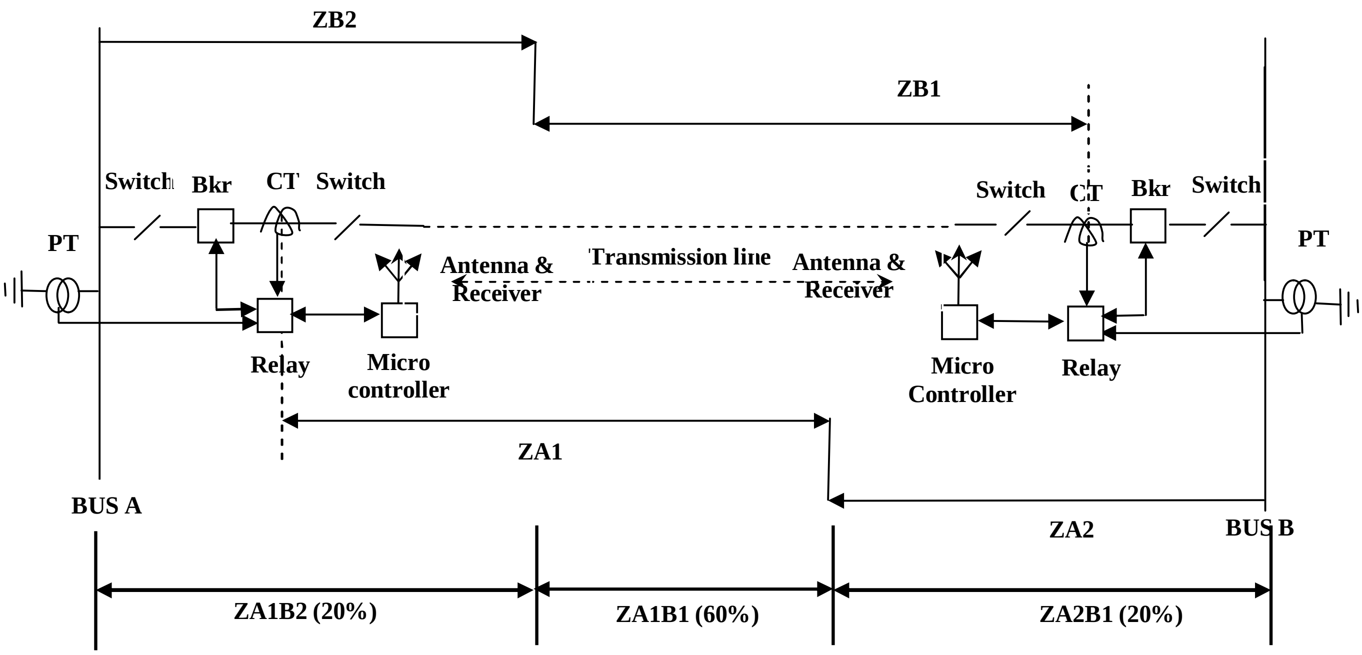

Fig 3. Wireless Aided Protection

The data transfer speed of ZigBee 802.15.4 is 250 kbps. It covered the rage of 65 KMs, Only one equipment is capable to take care of more number of feeders in a substation. It operates in the temperature range - 40°C to 85°C. The cost of wireless aided protection is very cheap compared to carrier equipment.

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IV. RESULTS & DISCUSSION

If any fault occurs in 110 KV transmission line, the simultaneous tripping of breakers on both ends are achieved by using ZigBee 804.15.2 based wireless aided protection to reduce the fault current. The comparative statement of time taken by the relays to give trip command to the circuit breakers on both ends without aided protection and with wireless aided protection are tabulated as below.

Fault Zones	Time taken by the relay to give trip command			
	Without aided protection		With wireless aided protection	
	Relay A	Relay B	Relay A	Relay B
ZA1B1	Instant	Instant	Instant	Instant
ZA1B2	Instant	**400 ms**	Instant	**Instant**
ZA2B1	**400 ms**	Instant	**Instant**	Instant

If the fault is in ZA1B1, it is zone 1 fault for both relays A and B. So the both end relays give trip command to the circuit breaker instantaneously in without aided protection as well as wireless aided protection.

If the fault is in ZA1B2, it is zone1 fault for the relay A and zone2 fault for relay B. So the relay at bus A senses the fault and gives trip command instantaneously and the relay at bus B gives trip command after 400 milliseconds in without aided protection. But in wireless aided protection, the relay at bus A senses the fault and gives trip command instantly to the circuit breaker at bus A and sends a signal to the other end relay through wireless equipment. The other end relay at bus B senses the fault and receives the signal from other end as confirmation and gives trip command to the circuit breaker at bus B instantaneously.

If the fault is in ZA2B1, it is zone1 fault for the relay B and zone2 fault for relay A. So the relay at bus B senses the fault and gives trip command instantaneously and the relay at bus A gives trip command after 400 milliseconds in without aided protection. But in wireless aided protection, the relay at bus B senses the fault and gives trip command instantly to the circuit breaker at bus B and sends a signal to the other end relay through wireless equipment. The other end relay at bus A senses the fault and receives the signal from other end as confirmation and gives trip command to the circuit breaker at bus A instantaneously.

The zone2 time delay of 400 milliseconds in 110 KV transmission line is eliminated successfully by using ZigBee 802.15.4 based wireless aided protection. Hence if any fault in 110 KV transmission line, both end relays give trip command to the circuit breaker instantaneously with the help of wireless aided protection. The results are displayed in the LCD display which is in the working model as shown figure4. If the ZigBee 802.15.4 based wireless aided protection is used in 110 KV system and below, the system has the following advantages

- It trips both end breakers instantaneously
- It reduces the fault current
- It improves the system stability
- It improves quality of the system
- It improves performance of the system
- It improves the life period of equipment.
- It reduces the mechanical stress on the generator rotor

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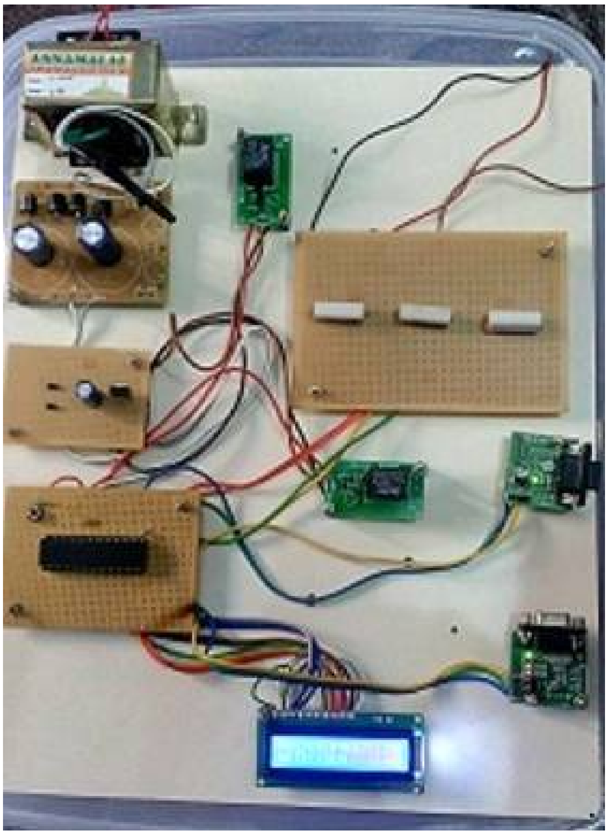

Fig 4 Working model of wireless aided protection

V. CONCLUSION

If any fault occurs in 110 KV transmission line, the breaker on both ends trip instantaneously to isolate the faulty element from the power system to reduce the fault current. It is achieved by using ZigBee 802.15.4 based Wireless aided protection. Hence the ZigBee 802.15.4 based Wireless aided protection is implemented in 110 KV transmission line successfully and the fault current is reduced by eliminating the relay time. It can be used in 230 KV system and above instead of carrier aided protection to reduce the cost of protection. The wireless aided protection can also be utilized in auto reclosure operation to reduce the interruption time. Hence the 110 KV system stability, quality, performance are improved by using ZigBee 802.15.4 based wireless aided protection.

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