Digital Protection of Power System
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Lecture 16
Digital Protection of Induction Motors - 1

Hello friends. So, in this lecture, we will discuss about the protection of induction motor, especially when we use the digital or numerical relays.

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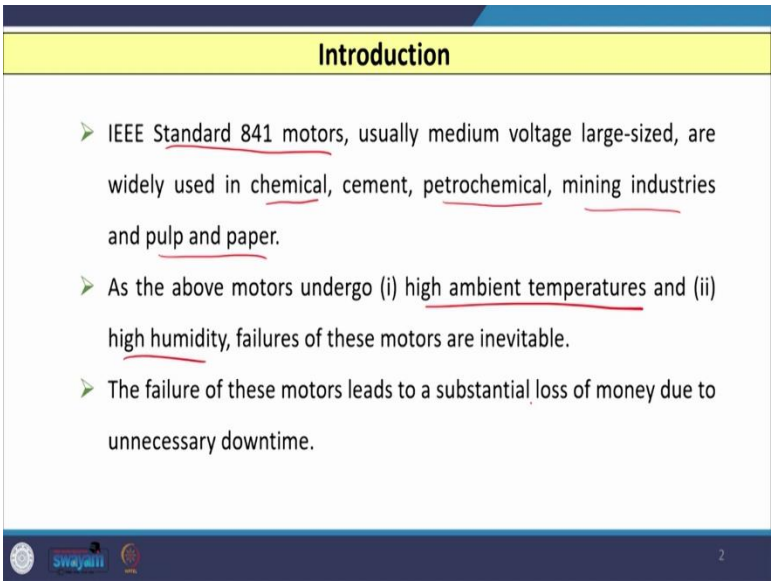

So, we know that mostly medium voltage large sized induction motors, and this motors are defined by IEEE standard known as 841 motors, they are widely used in different applications, they are used in chemical plants, they are also used in cement industries, they are also used in petrochemical industries, mining industries, pulp and paper industries, maybe milk industries and, etc.

So, as this motors are used or utilized in different industries, and these industries has different environment, so this motors will undergo high ambient temperatures and they are also affected by high humidity. So, failures of this motors are definitely inevitable. So, the failures of this motors lead to substantial loss of revenue, because in case of failure of motor, whatever downtime is there, this downtime is very high and if we are not able to reduce that downtime, then huge revenue loss that may be there.

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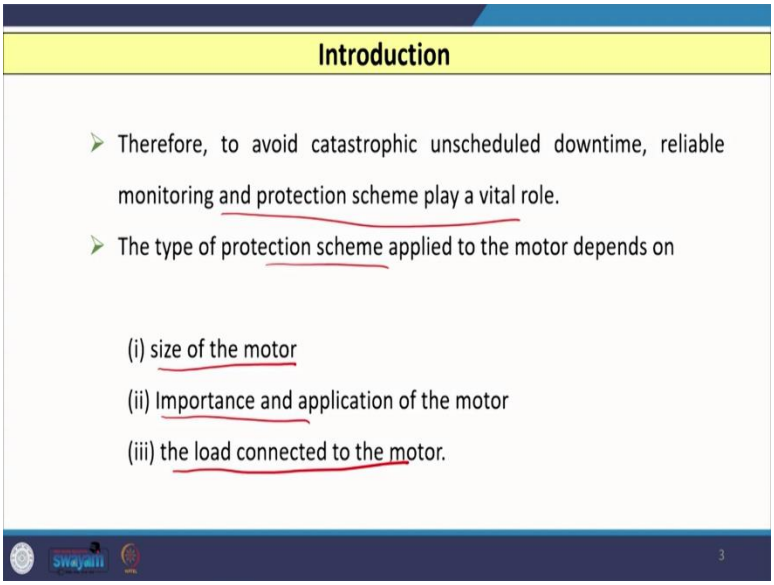

So, if we wish to avoid this unscheduled downtime, because of which revenue loss may occur, reliable monitoring and protection scheme that plays an important role. So, the type of protection scheme which we can use for protection of induction motor that depends mainly on three factors, the first factor is the size of the motor. So, what is the rating of the motor usually in HP or megawatt rating or kilowatt rating that is an important point.

The second parameter is the importance of induction motor and what is its application. So for which industries it is used for what application it is used, and what is its importance, that is also another parameter which is going to decide what type of protection scheme we will use for the protection of induction motor. The third parameter is the load connected to the motor. So, what type of load is connected what is the value of load that also plays an important role.

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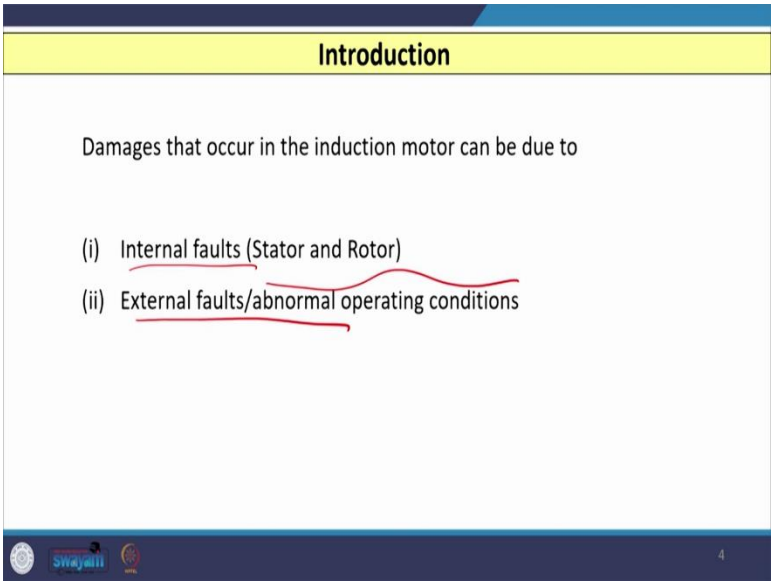

Now, regarding the damages that occur in case of induction motor, that is because of two main reasons the first if internal fault occurs inside the winding of the induction motor, maybe in the stator or rotor, then huge damage will occur. The second condition is because of the external faults, because those faults may impact the temperature or some other parameters of the induction motor or maybe some abnormal conditions are also there because of which the parameters of induction motor may change.

So, for both these cases, that means in case of internal faults and second in case of either external fault very near to the motor terminal or abnormal operating conditions, damage that may occur as far as induction motor is concerned.

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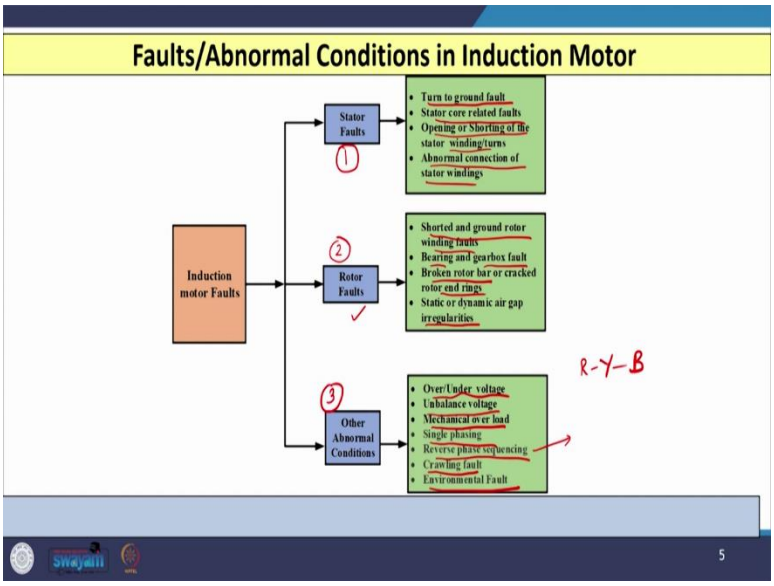

So, if I consider the internal faults inside the induction motor, then the first type that is known as the stator faults because these faults are going to occur in the stator of the induction motor. So in stator faults, the first faults are related to the turn to ground faults, the second are related to the stator core. So if fault occurs in the core of the stator or if it occurs in the different turns of the stator winding, then also the damage of the induction motor occurs.

The third case is the opening or shorting of maybe few turns or few windings. So because of that also a huge current will flow and your data of induction motor may damage and the fourth one is the abnormal connection of stator winding. So if stator windings are connected wrongly then also this type of faults may occur.

The second category of faults are known as rotor faults, because faults are going to occur in the rotor of the induction motor. So in this case, shorted and ground rotor winding fault are there fault may occur in case of bearing or gearbox. So, if these are the cases, then also your rotor may damage sometimes your rotor may have a breakage because of maybe some other reasons or maybe your end rings of the rotor, they may also damage or they may also cracked.

So, broken rotor and damage of the end ring these are also an important faults which are going to occur in the rotor of the induction motor. Sometimes irregularities may present in the air gap maybe because of static or dynamic reasons and because of that also the rotor faults may occur in the induction motor. The third category that is maybe some other abnormal conditions because of which the voltages at the terminal of the induction motor may change so over voltage or under

voltage me observed sometimes voltages of all the three phases are not balanced on balance voltage is also there.

Mechanical overloading may observed single phasing is also there because if three phase induction motor is running and one of the phase of the induction motor disconnects because of some reason, then that phenomena is known as single phasing phenomena. So, in this case also the sequence currents may flow and that is going to damage the induction motor.

Reverse phase sequencing so if let us say phase sequencing used that is RYB and because of some reason, if phase sequence becomes RBY or some other then the negative sequence current may flow and that may damage the induction motor. Sometimes crawling can also be observed specially when the sinusoidal voltages are not available or not given as an input to the induction motor.

So, in this case when sinusoidal inputs are not given to the induction motor then the motor may run or may draw a very small small value of current roughly one fifth or one seventh of the full load current of the motor. And in this case this phenomenon is known as crawling. Motor may damage because of environmental effect maybe if you are using induction motor for some different applications, where temperature is very high, it is a humid environment then also your motor may damage.

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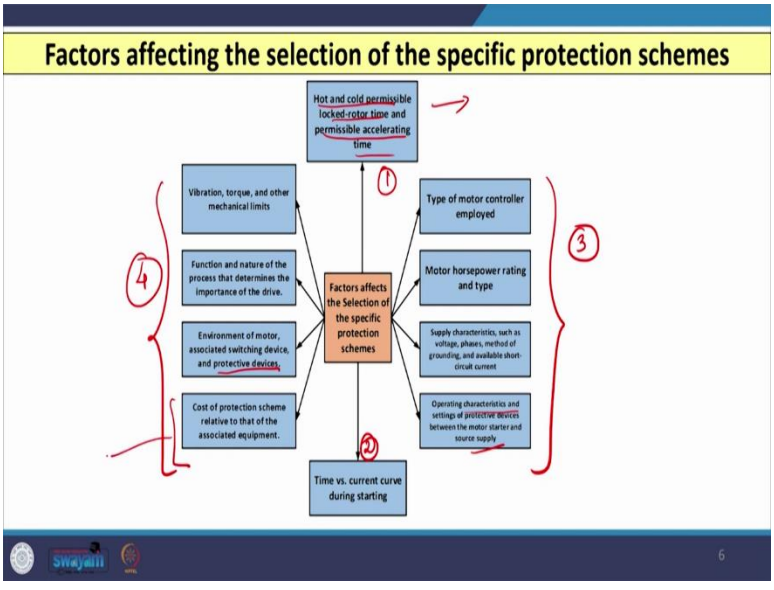

So, obviously if we wish to protect the induction motor, then we need some protective schemes. So, now the question comes what factors we need to consider when we design or when we select protective schemes for the protection of large induction motors. So, let us see what are the factors we need to consider.

So, the first factor is the locked rotor time for the induction motor when motor is running in hot condition or when motor is in cold condition in both cases, we need locked rotor time of the motor. And we also need permissible accelerating time of the induction motor. So when you start the motor and when motor comes or motor is running in steady state condition that time depends on inertia of the motor.

So that is also an important parameter because of which our protective scheme may be affected. The second we can say the time versus current curve, specially at the time of starting of induction motor because when you start the motor, motor will draw a very high current and whatever protective device you have used that may also trip so we want to avoid mild tripping of this devices specially in case of starting of induction motor. So this is also an another important parameter.

The third parameter are related to the type of motor controller which we have used in the motor, what is the rating of the motor and what is the type of the motor then what is the supply characteristic that means we are using for let us say a single phase motor or three phase motor, what is the grounding used or what type of method of grounding is used for the motor or what is the short circuit current the motor can withstand maybe for a few time period.

So those things are also important and those parameters we need to consider when we design the protective schemes for induction motor. Along with this maybe operating characteristic and settings of protective device between motor starter and source of supply that also play an important role.

After that, another parameters are maybe what is the vibration and torque and other mechanical limits that is imposed on the motor, what is the function and nature of the process time that determines the importance of the drive used inside the induction motor and what is the environment of the motor whether it is used for very high-end temperature or maybe in humid environment and what type of protective device we want to use that also play an important role.

And the very important point is what is the cost of the equipment because, if cost of equipment is x, then the thumb rule is there the cost of protective device which we are going to use, that should not exceed 15 percent of the cost of the equipment to be protected. So, with this parameters, which we have discussed, if we combine all these parameters, then based on characteristic of these parameters, based on the nature of these parameters, we have to design the protective scheme for the protection of induction motors.

Nowadays, we know that digital relays or numerical relays are widely used, in earlier days. We know that first and second generation of relays were used like electromechanical and static, but nowadays, the digital or numerical relays are widely used by utilities.

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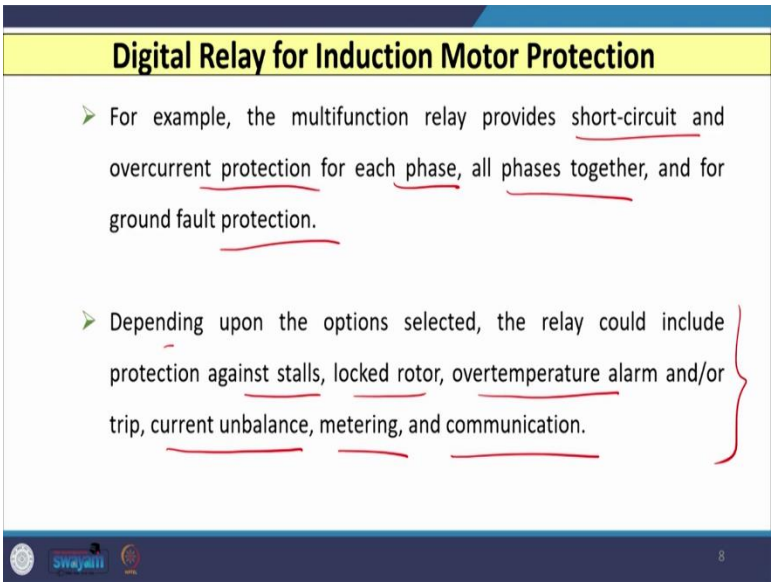

And when we use the digital relay for the protection of induction motor, this type of relays are also sometimes known as multifunction relays or motor management relays, more or less name is same, but all are nothing but the digital relay or numerical relay.

This relay incorporates all the protective functions that are normally achieved individually, when we use let us say electromechanical relay for the protection of induction motor, then for overcurrent we have to go for another relay, maybe for locked rotor protection, we have to go for another relay like that. However, if I use digital relay, then digital relay incorporates all the functions or features in a single unit.

So, when we use the multifunction relay, as I told you, all the protection elements are incorporated in one enclosure and that is nothing but the features of the digital relay. So, if we consider for example, a multifunction or motor management relay as a digital relay, then we can say that short circuit overcurrent protection, so overcurrent protection is normally used for protection against short circuits for individual phase for all the phases and for ground fault all are clubbed in a single unit.

So, all features are available in a single relay. Further along with this you can see the protection against stalling is also available locked rotor protection is also available then you can say alarm if, if it is required in case of increase in temperature or maybe protection is required in case of reverse phase sequence or unbalanced voltages. If you want to measure something metering function is required, if communication is required, that all these functions are clubbed and available in a single unit that is known as digital relay.

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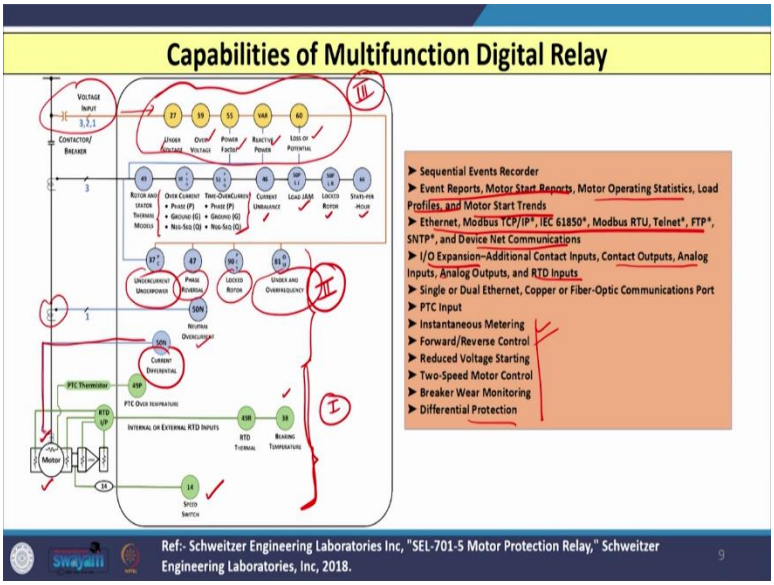

So, now, let us see what are the capabilities of multifunction digital relay or motor management relay? So, as you can see in the diagram (as shown in above slide), the motor is protected by different protective devices or element. So, you can see this lower portion green color is meant for the winding temperature detection and speed detection.

So, if you want to measure the speed of the induction motor or if you want to measure the maybe a bearing temperature or some other then you can go for either thermistor or maybe RTD resistance

temperature detector, maybe you can use internal or external RTD inputs of the relay and this portion lower portion in green color that is meant for that purpose.

Further along with that if you move ahead, then from here you can see the other portion the second part that is related with you can see the differential protection. So one separate CT is available here (as shown in above slide) from which the output is given to the differential protection, you may have again the neutral overcurrent for with separate CT that is also there.

And as I told you, if short circuit occurs then protection against short circuit that can be also achieved by overcurrent this are the instantaneous elements maybe for phase ground and negative sequence. And if you want some delayed protection, inverse minimum define a time delay then time overcurrent protection is also there for phase ground and negative sequence.

Along with this current unbalance relays also there. So, this function is also available in digital relay locked rotor protection function is also available, load jam function is also available and in in an hour how many times you have started the motor that function is or that measurement is also available in the digital relay.

Along with this under current and under power measurement, phase reversal measurement locked rotor protection and under and over frequency function because these are all abnormalities that is going to occur in the induction motor. So, these features are also incorporated in digital relay.

Then sometimes, if you use some other function like as I told you power or maybe a loss of potential or reactive power, power factor over voltage under voltage, then obviously, you need some voltage transformer or potential transformer. So, that is given here and the output of this PT or VT you can connect the relays like voltage base relay, which is meant for over or under voltage.

Maybe you can measure power factor reactive power or maybe some other feature. So, all these are related for that purpose. So, third case is again we have to use the output of PT or voltage transformer so, that you can have some additional features available in the digital relay along with that for specific event like let us say you need to generate the motor startup reports what is the starting current of induction motor what is the acceleration type, etc.

Operating statistics you want to just show load profiles you want to display or motor start trends you want to show then that type of features are also available in digital relay. Along with that, this

relay will provide several communications in terms of let us say Ethernet, Modbus, TCP IP, IEC 61850 and FTP and so on, SNTP.

Along with this several input output expansions are also available maybe you can have let us say analog input analog output, maybe some inputs for resistance temperature detector for our temperature measurement and after that you may have let us say the metering purpose.

So, instantaneous metering that is also available control facilities also available like let us say reduce voltage starting or maybe breaker we are monitoring or differential protection. So, such type of additional features are also available in a single digital or multifunction digital relay. So, this all are the capabilities of digital relay which is available in single unit and that features we want to study in this lecture.

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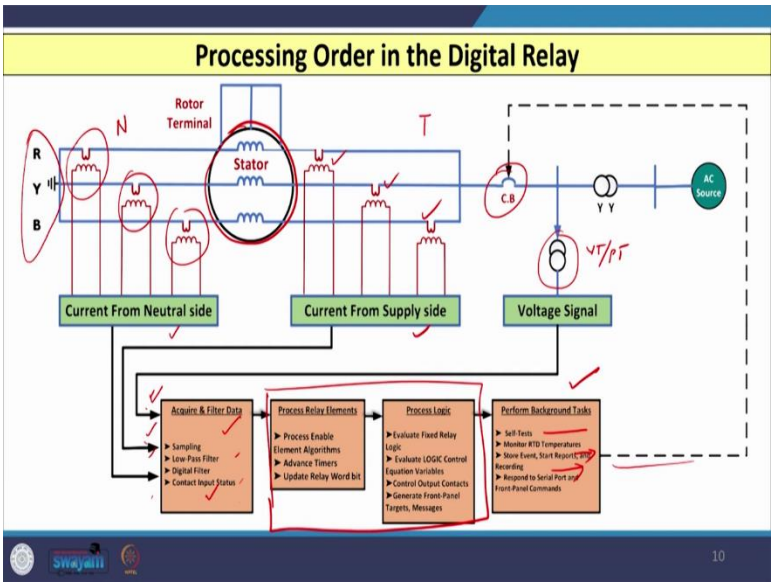

Now, before we start to discuss the various functions and capabilities in details for digital relays specially used for protection of induction motor, let us see what is the processing order in the digital relay. So, you can see I have shown here (as shown in above slide) the three phase diagram where the stator of the motor is shown here in three phase RYB on one side where the neutral side is there. So there I have connected three CTs.

So, these are the CTs of neutral side and on terminal side. So, this is your terminal side and this is your neutral side (as shown in above slide). So on terminal side also I have connected three CTs.

So, I am capturing the CT secondary currents from neutral side as well as supply side and I am giving as an input to the for processing of the digital relay.

Along with that, I am also giving input from the secondary of the voltage transformer or potential transformer as I tell you, so, this is your VT or PT and output of that that is also given as one of the input to the relay so that relay can process and perform its functions. Sometimes if required, you can also have some additional input maybe from externally some digital input or maybe status of some devices like breakers and, etc, that also you can give.

So, once you give the CT and PT inputs to the digital relay, then the first part is the processing of this acquired signal. So we have to remove the harmonics or noise. So for that we have to go for low pass filter or anti aliasing filter, maybe you have digital filters are also there. And you have to do it this along with filtering you have to go for sampling so that you can easily convert this signals or this analog signals into digital signals after that the second and third block are related to the algorithm part.

So, whatever output is available relay may convert into phasor values. So, this values are instantaneous values available after sampling and processing and whatever the sample values are available depending upon the sampling frequency and number of samples taken in a cycle, you may convert or really may convert into phasor values, and those phasor values may use for further for taking any decision. So, whatever logics are there those are worked or implemented here computation is carried out in this part, and then maybe some outputs are given by the relay maybe in the form of let us say, the output contacts some outputs are given, let us say some front panel targets or messages are also given. So, that if any abnormal condition is there, then the operator may take an appropriate decision.

And finally, in the fourth block certain tests are carried out because we know that digital relay is capable to carry out self checking and self testing maybe you can have some monitoring of several RTD temperatures. So, if finding temperature is to be observed continuously, so, that you can do and maybe your relay can respond to serial port and front panel commands to initiate the command to trip the let us say circuit breaker.

So, if I wish to trip the circuit breaker then some command is initiated from the relay. So, this is nothing but the processing order in the digital relay.

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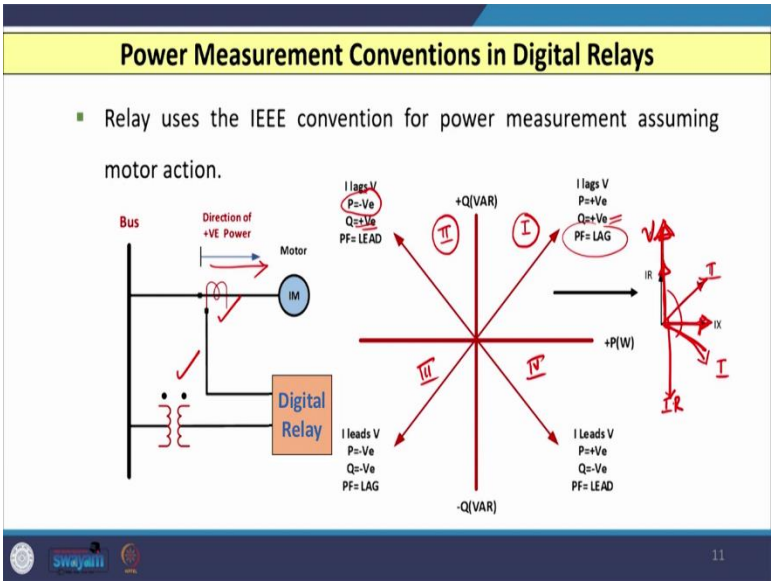

Now, with this background, let us see how the power measurement conventions is followed in digital relays. So, you can see that normally all the digital relays they use IEEE convention for power measurement assuming that it is a motoring action. So, the direction of positive power is in this direction when current or induction motor takes the input. So, through CT and PT I have shown here.

So, if I draw if I represent this in a four quadrant figure or wave shape, then you can see (as shown in above slide) that I have shown here for quadrant first, second, third and fourth and in each quadrant, I have shown the active power on x axis positive and the negative and reactive power on y axis positive and negative.

So, in the first quadrant, if you see then (as shown in above slide) the usually I assuming that my voltage is a reference quantity, so the current lags the voltage assuming that when motor draws the current and being an inductive element current lags the voltage. So, in this case the positive or active power is like this and reactive power is like this (as shown in above slide).

So, your current lags the voltage and power factor is like lagging. If you consider the second quadrant, then again being the voltage as taking the voltage as a reference, the only thing is you can see here your active power that becomes negative. So, your I_R that comes here in the opposite direction, 180° out of phase.

Your reactive power that is still positive. So, it remains as it is and if you draw the resultant, then your resultant current will be I like this, I still lags the voltage. So, you can have or you have the operating point that is in the second quadrant same way you can go for the operation of third and fourth quadrant accordingly.

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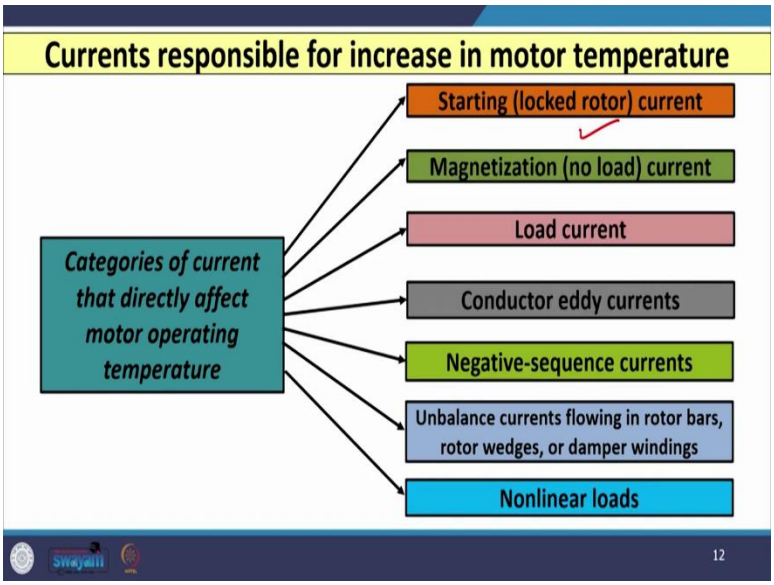

Now, if I consider the motor temperature means because we know that whenever anything or any abnormal condition occurs inside the induction motor then winding temperature increases. So, the increase in winding temperature depends on so, many parameters for different parameters due to which the current may increase.

So, in this case the first important current is the starting current of the induction motor because we know that it is very high almost five to six times the full load current. Second is the no load current of the induction motor. The third is the actual load current, when motor is running in steady state condition.

Eddy currents, the negative sequence currents in case of abnormal condition or maybe in case of fault, unbalanced currents that flows through the rotor bars or maybe in the damper windings. And when nonlinear loads are there, then also the currents are not balanced. So, all these currents are going to make an impact on the motor temperature and because of these motor temperature increases and because of this increase in motor temperature failure of the motor may observe.

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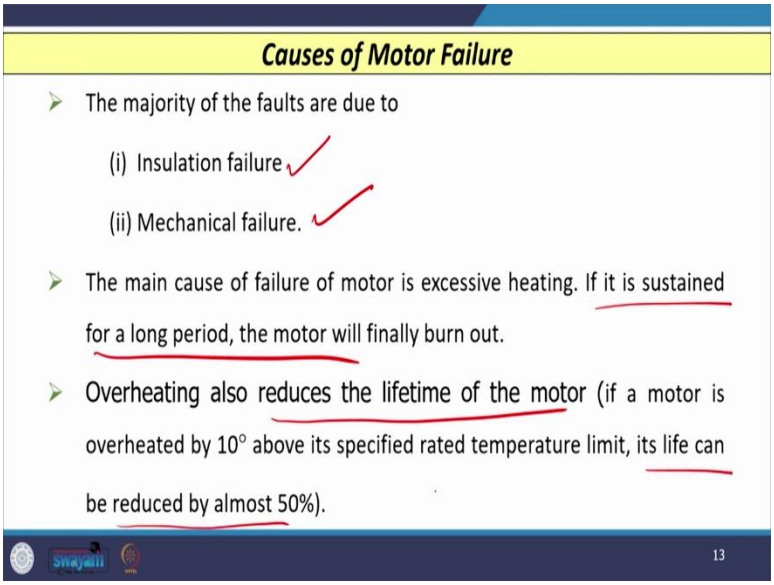

So, if we consider or if we take the causes of motor failure then majority of faults are either due to insulation failure or maybe because of the mechanical failure. So, main cause of failure of motor is excessive heating and that is because of different currents as I told you earlier maybe because of starting current or full load current or negative sequence current.

So, if this is sustained for a longer duration, then your motor or winding of the motor may burn and the statistics shows that in case of overheating, if motor is overheated by 10° about the with reference to its rated temperature then its life of the insulation may reduce by almost 50 percent. So, that is why because of this reason, we have to again avoid this failure of the motor then we have to go for digital relay.

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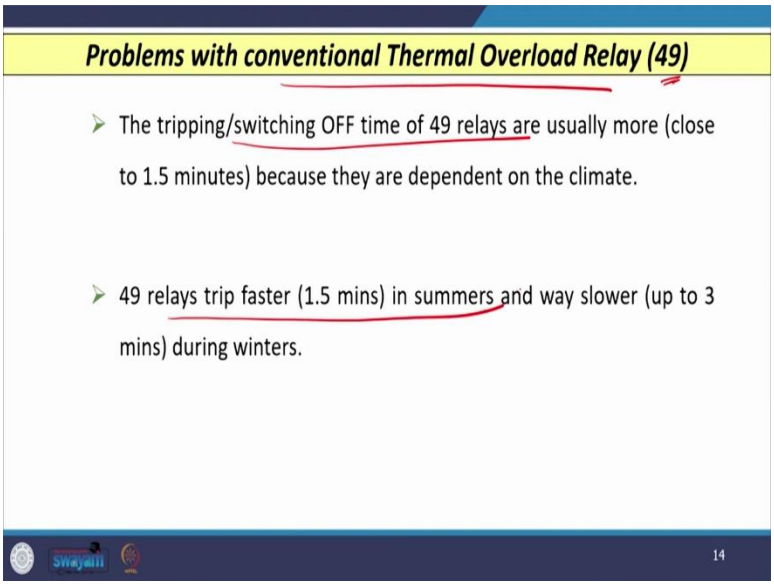

Now, the question is earlier whatever relays we were using electromechanical and static, they are also compatible and they are also taking care of induction motor when any fault occurs or even maybe any installation failure is there then the reason or question may arise what are the reasons we are moving from conventional relay to the digital relay specially for the protection of induction motor.

So, if I consider one of the element of the relay that is thermal overload relay that is number is 49. So, if I use electromechanical or static relays, earlier generation relays, then tripping time given that is of the order of minutes almost 1.5 minutes and this tripping time depends on the climate change. So, normally in summers this electromechanical or static relays trip in 1.5 minutes and in winter time it will take almost double time it will it will take roughly around 3 minutes.

So, if we allow to run the motor for 1.5 times and during this period or 3 minutes or 1.5 minutes and during this period, if coil or winding of the induction motor draws a large current may be higher than the full load current then the winding of the motor may damage.

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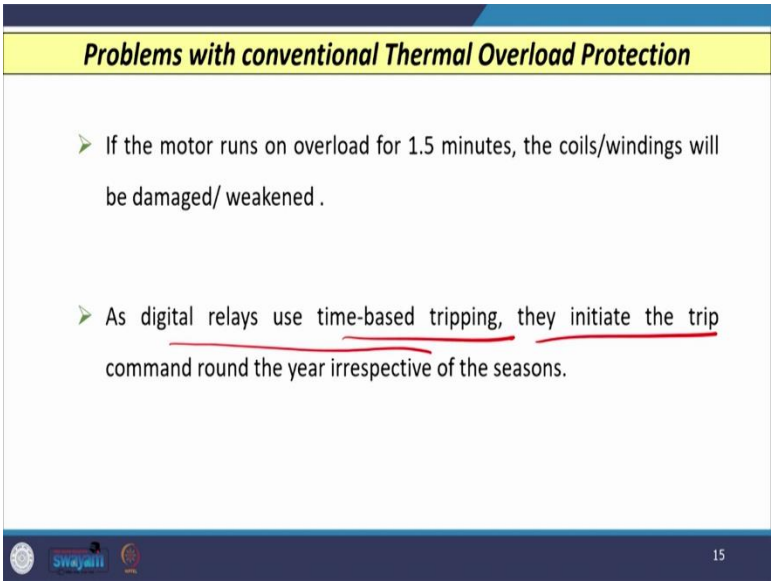

In other case opposite to that if I use the digital relay, then the tripping of the digital relay is achieved based on the time and they initiate the trip command round year irrespective of the seasons. So, that is why we have to move or switch over from the conventional electromechanical or static relay to the digital relay because my digital relay in this condition when motor draws beyond full load current and in overloading is there then the digital relay will operate in a very small period of or fraction of second time compared to the earlier generation electromechanical or static relays.

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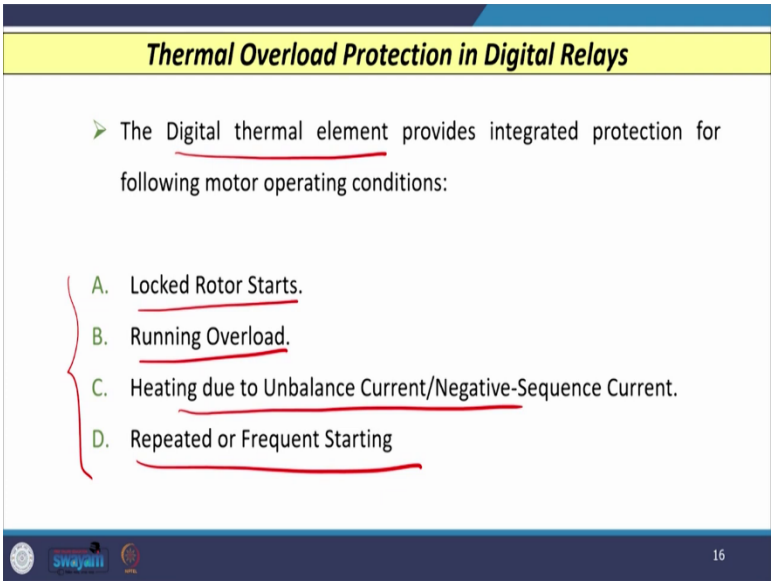

So, if we consider the digital relays then in digital relay specially one element is provided that is known as digital thermal element and this element provides overall comprehensive protection for different motor operating conditions. And, this conditions are locked rotor maybe running overloads or maybe heating because of unbalanced current or negative sequence current and repeated or frequent starting of the induction motor.

So any of these conditions are there the digital thermal element is provided in digital relay as one of the elements or one of the function which gives integrated protection for all this phenomenon or cases or conditions compared to the previous generation electromechanical and static relays in a better way.

So, that is why we will go for or we will switch over from the electromechanical or static relay to the digital relay. So in this lecture, we have discussed the features or capabilities of the digital relay or digital element used for the protection of induction motor and we have seen that different functions are clubbed in a single unit and that is also known as motor management relay or multifunction relay.

And then, we have also seen that the thermal overload protection if we wish to achieve in a digital relay, then digital relay has separate element which is known as digital thermal element which is going to take care of all such situations that is going to be observed by the induction motor maybe during starting or maybe during lock rotor condition or maybe in some other abnormal condition and that is taken care by this digital thermal element in a digital relay very effectively.

So, whatever the parameters we have discussed based on which we can decide or think on what type of protection scheme we can use for the induction motor, then considering those parameters, digital relay plays an important role, and it is the best option which we can select and utilize for the protection of induction motor. So, another further feature of the induction motor in case of digital relays, we will discuss in the next lecture. Thank you.