Introduction to Smart Grid
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Lecture – 22
Smart Grid Protection – IV

Good morning to all of you, in this lecture we will discuss about the Smart Grid Protection. In continuation to our previous lecture we will continue with adaptive protection schemes for the micro grid system. If we will see the previous lecture we have discussed the adaptive protection scheme, using the directional over current relay and in this flow diagram the process the steps are involved here.

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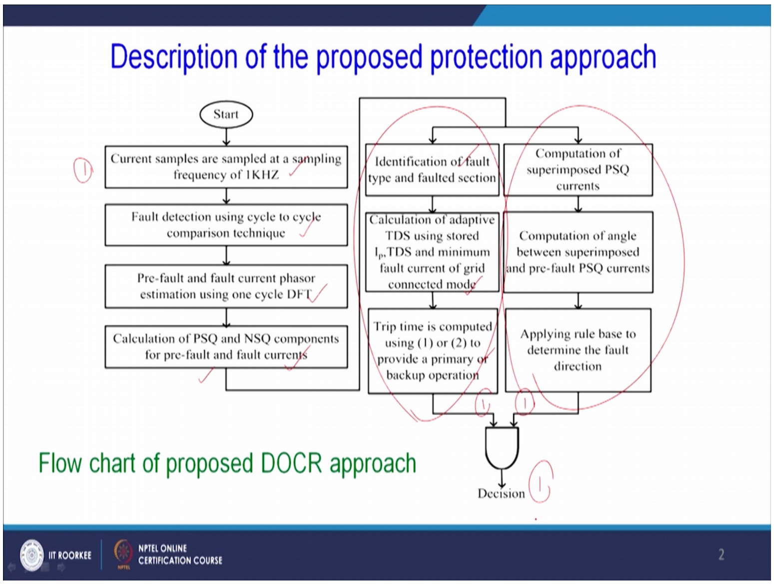

In the first step current samples are going to be samples at the sampling frequency of 1 kilo hertz, and then the fault is going to be detected. And then the phase are going to be estimated using the DFT that is discrete Fourier transform technique.

And after that this positive and negative sequence components of pre fault and fault currents are going to be estimated. And after identified this fault type then the faulted section is going to be identified and corresponding TDS and fault settings of the over current relay are going to be calculated.

And this particular being is responsible for the over current relay part and this one is responsible for the directional part, and both the outputs like this is 1 if this is 1 then the final output is going to be 1.

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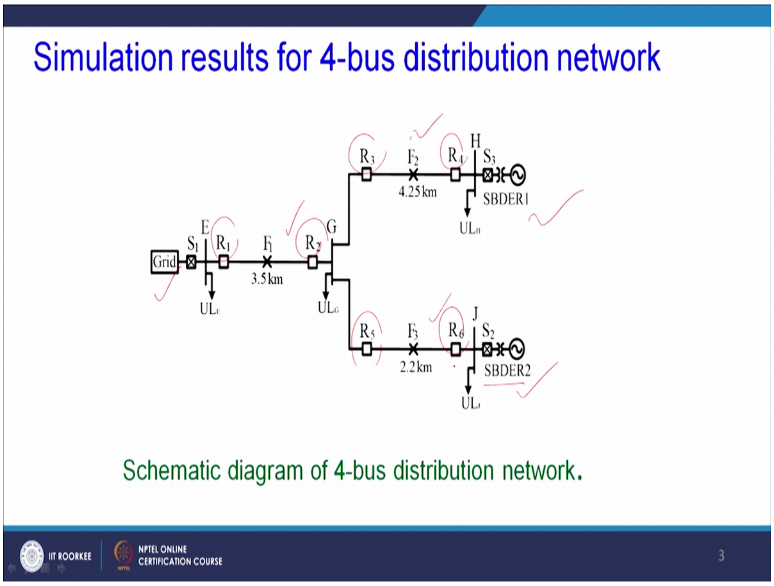

Now, to validate this particular technique we have taken one 4 bus network, you can see here that this is our grid and this is 1 renewable energy source, and this is renewable energy source 2, and these two are basically the synchronous based renewable energy source.

This SBDER stands for synchronous based derenewable sources. Now, we have four line I mean three lines. Here this line one, this is line two, and this is line three, and this first line is protected using this two relays that is R 1 and R 2, and the second line is protected basically using this two relays R 3, R 4. And third line is protected using this R 5 and R 6, and in this proposed technique all this relays are directional over current relays.

Here basically in today's state in digital relaying platform. If we are using basically the directional over current relay we are not going to put any cost, because almost all the relays are multi-functional in nature. We can either use the relay as directional over current relay or only over current relaying or we can also use only the directional relay or distance relay, differential relay.

So, that is why this is one of the advantage of the digital relaying platform. Now using that particular system results are produced using the software that is RS cad. And that RS cad software is available within this RTDS. That is your real time digital simulator, why this platform is chosen? Because this particular platform meets the real vault and that particular on certainties whatever we phase saturation, transience whatever the sort of like on even I mean on certainties are present inside the actual power network.

Those uncertainties that those difficulties or those uncertainties can be modelled using this RTDS platform, real time digital simulator. And taking that particular platform results I mean system is simulated and corresponding results are produced.

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Results for Grid-connected mode of operation

Results of the calculation of fault currents, settings and time of operation of DOCRs for grid connected mode

FP (j)	PR/BR (i)	Adaptive approach $I^c_{p/bj}$, A	Adaptive approach $TDS^c_{p/bj}$	Adaptive approach $I^c_{1F/2Fij}$ A	Adaptive approach $t^c_{1F/2Fij}$, s	Adaptive approach CTI	$f(M_{p/bj})$	Conventional approach $I^c_{p/bj}$, A	Conventional approach $TDS^c_{p/bj}$	Conventional approach I^c_{1Fij} A	Conventional approach $t^c_{1F/2Fij}$, s	Conventional approach CTI
F1	R1	0.636	0.150	6.856	0.431	-	0.049	0.636	0.150	6.856	0.431	-
	R2	0.608	0.050	1.842	0.312	-	0.022	0.608	0.050	1.842	0.312	-
	R4	0.252	0.142	1.245	0.613	0.301	0.032	0.437	0.142	2.058	0.631	0.319
	R6	0.270	0.113	0.954	0.618	0.306	0.023	0.467	0.113	1.493	0.673	0.360
F2	R4	0.437	0.142	2.872	0.518	-	0.038	0.437	0.142	2.872	0.518	-
	R3	0.450	0.100	4.077	0.311	-	0.045	0.450	0.100	4.077	0.311	-
	R1	0.367	0.150	1.970	0.615	0.304	0.034	0.636	0.150	3.012	0.665	0.354
	R6	0.270	0.113	0.959	0.616	0.305	0.026	0.467	0.113	1.466	0.684	0.373
F3	R6	0.467	0.113	3.142	0.407	-	0.039	0.467	0.113	3.142	0.407	-
	R5	0.477	0.100	3.952	0.324	-	0.043	0.477	0.100	3.952	0.324	-
	R1	0.367	0.150	1.762	0.659	0.335	0.032	0.636	0.150	2.694	0.717	0.393
	R4	0.252	0.142	1.214	0.623	0.299	0.032	0.437	0.142	1.854	0.678	0.354

The first result is for grid connected mode of operation, because as already we have discussed the micro grid may operate in neither grid connected mode or it may also operate in islanded mode of operation.

So, we have to check whatever the algorithm or protection algorithm we are going to develop, all the algorithm should be checked properly for grid connected mode of operation as well as for the islanded mode of operation. Coming to this first mode of operation that is grid connected mode of operation. The results for this case, this is for the first table source for the results for adaptive approach and this one is for the conventional approach.

In this adaptive approach if you could see that this fault F 1, if I will go back this is the fault situation F1. And this fault is created in line 1 and this fault F 1 is going to be cleared by this R 1 and R 2 primary relays. And yes of course, if this R 1 R 2 primary relays fails then this R 4 and R 6 these are the backup relays they are responsible to clear that particular fault.

And coming to this adaptive approach for this particular fault F 1, we can see here this is the pick-up, I mean current or before fault this is the TDS setting. And this is the fault current table and this is the time of clearing the fault. See finally, the point here is our check will be that CTI this is the, this coordination time interval should be perfect that should be within 0.3 to 0 to 5 second. And yes we have attained this particular value and this CTI is well within this 0.301 second that is why this particular approach adaptive approach is successful while we are integrating this renewable source. May be we have synchronous based DGs or may we have this inverter based renewable energy sources.

Now; however, if we will just come to the conventional approach what is this conventional approach? As already we have discussed, in conventional directional over currents relaying principle we assume that the block setting and TDS or TMS of the over current relay, I have just say to be fixed value. Irrespective of the mode of operation whether this grid is operating in grid connected mode or islanded mode or it at may be in with different types of renewable sources. So, always in conventional approach we depend on a fixed type of settings of the over current relay or directional relay. So, that is why this conventional approach is producing basically of 0.319. I mean yes it is of course, within this 0.3 to 0.5 second.

But here our target is to be within 0.3 second only, that is what I mean it will be just 0.9 0.30 second, but here it is exceeding this value 0.319 and this case it is 0.360 second. So, if you will see for different fault positions like F 2 and F 3 similar results are gathered and it is found that finally, this particular proposed to adaptive approach is providing correct result in comparison to the conventional approach.

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Results for Islanded mode of operation

Results of the calculation of fault currents, settings and time of operation of DOCRs for islanded mode

FP (j)	PR/ BR (i)	Adaptive approach					f_{new} $(M_{p/bj})$	Conventional approach				
		$I^c_{new\_p/bj}$, A	$TDS^c_{new\_p/bj}$	$I^c_{1F/2Fij}$, A	$t^c_{1F/2Fij}$, s	CTI		$I^c_{p/bj}$, A	$TDS^c_{p/bj}$	I^c_{1Fij}, A	t^c_{1Fij}, s	CTI
F1	R2	0.153	0.085	1.012	0.309	-	0.038	0.608	0.050	1.012	0.683	-
	R4	0.158	0.130	0.682	0.613	0.303	0.030	0.437	0.142	1.043	1.133	0.450
	R6	0.189	0.119	0.728	0.612	0.302	0.027	0.467	0.113	1.114	0.902	0.219
F2	R4	0.273	0.123	1.405	0.518	-	0.033	0.437	0.142	1.405	0.841	-
	R3	0.282	0.050	0.852	0.312	-	0.022	0.450	0.100	0.852	1.090	-
	R6	0.189	0.122	0.744	0.616	0.303	0.028	0.467	0.113	1.138	0.880	-0.20
F3	R6	0.328	0.119	2.418	0.407	-	0.041	0.467	0.113	2.418	0.473	-
	R5	0.334	0.063	1.278	0.324	-	0.027	0.477	0.100	1.278	0.703	-
	R4	0.158	0.130	0.665	0.623	0.299	0.029	0.437	0.142	1.017	1.167	0.437

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Now, this is for the results for the islanded mode of operation, this islanded mode of operation means when the main grid is disconnected from the rest of the micro grid system. So, in that case also we have to check whether this relays are properly coordinated or not. That is also essential because let us say during islanded mode of operations some of the relays are miss coordinated and they are just going to trip again.

So, unnecessarily we are going to lose the healthy sections, because the islanded mode is not basically a faulty mode right. So, that is why this only this relays are reactive during the faulty sections or fault situation. Otherwise they should not react may be it is a grid connected mode or it may be a islanded mode of operation.

In this case also if you could see this particular table the left side is basically for adaptive approach and the second column is for conventional approach. Now here the same discussion I will do that the CTI is our target that the coordination time interval should be equal to 40.3 right. So, here also same thing had happened, it is going to be 0.303 for this particular fault F 1.

And, but it will come to the conventional approach, where we have not changed the plug setting or TDS of the corresponding over current relay. Then the corresponding CTI is exceeding it is not exactly point 03 second. I mean 0 point 3 second, rather it is 0.45 second. That means, it may also miscoordinate that if you will use it will depend on the conventional approach. Now, yes along with the over current relay performance we also assessed the performance of the directional components.

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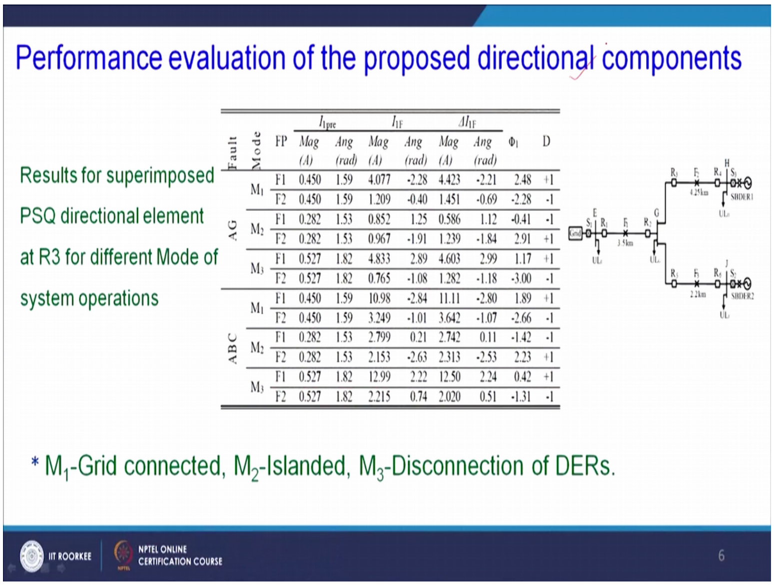

Fault	Mode	FP	I_{1pre} Mag (A)	I_{1pre} Ang (rad)	I_{1F} Mag (A)	I_{1F} Ang (rad)	ΔI_{1F} Mag (A)	ΔI_{1F} Ang (rad)	Φ_1	D
AG	M_1	F1	0.450	1.59	4.077	-2.28	4.423	-2.21	2.48	+1
		F2	0.450	1.59	1.209	-0.40	1.451	-0.69	-2.28	-1
	M_2	F1	0.282	1.53	0.852	1.25	0.586	1.12	-0.41	-1
		F2	0.282	1.53	0.967	-1.91	1.239	-1.84	2.91	+1
	M_3	F1	0.527	1.82	4.833	2.89	4.603	2.99	1.17	+1
		F2	0.527	1.82	0.765	-1.08	1.282	-1.18	-3.00	-1
ABC	M_1	F1	0.450	1.59	10.98	-2.84	11.11	-2.80	1.89	+1
		F2	0.450	1.59	3.249	-1.01	3.642	-1.07	-2.66	-1
	M_2	F1	0.282	1.53	2.799	0.21	2.742	0.11	-1.42	-1
		F2	0.282	1.53	2.153	-2.63	2.313	-2.53	2.23	+1
	M_3	F1	0.527	1.82	12.99	2.22	12.50	2.24	0.42	+1
		F2	0.527	1.82	2.215	0.74	2.020	0.51	-1.31	-1

This is the directional component and here is the system and you could see that for different types of faults this is AG fault, ABC fault and corresponding directional elements is here evaluated. And if you could see this is F 1 is basically this if we if we consider this relay, I mean this M 1, M 2, M 3, different modes of operations. This M 1 stands for grid connected mode, M 2 is islanded mode of operation, M 3 is disconnection of DERS.

Why this M 3 stands for like in micro grid system it may happens that may be we are going to lose some kind of renewable energy sources. We have many number of renewable energy sources which are connected to the respective buses, I mean particular locations. Now let us say due to some fault or some due to some maintenance problem 1 or 2 d are going to be out of order I mean it is out of service.

So, in that case also our relay should be intact and they should coordinate to each other properly, because dis connection of DERS basically it is not a faulty case. Now here for this M 1 that is the grid connected mode M 2 and M 3 for all the cases this particular directional unit is operating fine. If it is plus this plus designs I mean it describes, the fault is basically behind the relay if it is minus 1 then this fault is in front of the relay.

So, these are different situations we have created and we can also try by yourself by taking the system and taking the particular data and then corresponding results can be obtained. And this is the particular compass plot for these phases to make it more clear that I will just explain one, here the programs like for easy fault type and the fault position is F 1 during the grid connected mode.

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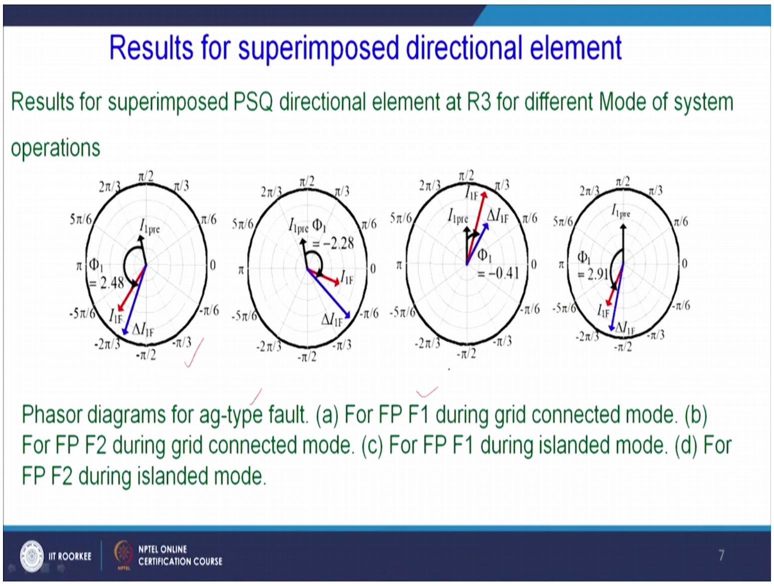

The first figure is for the fault at F 1 position and for the grid connected mode of operation of the micro grid system. Now here this is the position of I 1 pre, the fault currents the perceive sequence pre fault current which is flowing through the relay that is the position. And this is your I1 F, if the fault is located at the F 1 position the corresponding positive sequence current this is the I1 F, And this is my superimposed fault current this is the resultant of this particular between this I1 pre and I1 F.

And so, it lies here, and as we are taking the angle between this superimposed current and I1 pre; so, that is why this angle is basically if you could see here angle between this and this is going to be what? Because it is leading this delta I1 F is leading to delta I1 pre as a result. The angle is going to be positive that is what is written here plus 2.48 radial, all this angle are basically in radian.

Now, if you will come to this one the second one the second figure that is for the fault position F 2 during the grid connected mode of operation of the micro grid system. And here it is just the opposite case, because we are taking for the particular grid mode of operation. That is why this I1 pre is going to be constant, that this basically it is a flow of power the power flow direction that is why this phasor position I1 pre is going to be constant. Whether it is basically for F 1 position or F 2 position that is why here this I1 pre-position is constant as the previous case.

Now, here for this fault position this is the fault current phasor and this is corresponding resultant, between this I1 pre and I1 F that is the superimposed fault current. Now this if you could see that in this case this delta I1 F is basically lagging to this I1 pre, and that is why this angle is going to be negative minus 2.28 radian.

So, this is a very good I mean assessment using this mat lab, you can see easily that how these phasors are lying within this polar plot. Now we have done a very good laboratory arrangement inside this department of electrical engineering IIT Roorkee, using this RTDS as I said from the beginning. That we have used this real time digital simulator platform for the simulation of different types of micro grid system and this is a very I mean advantages case that in RTDS , there is availability of solar system, wind system, fuel cells batteries. So, all kind of renewable sources are basically available in this RTDS software.

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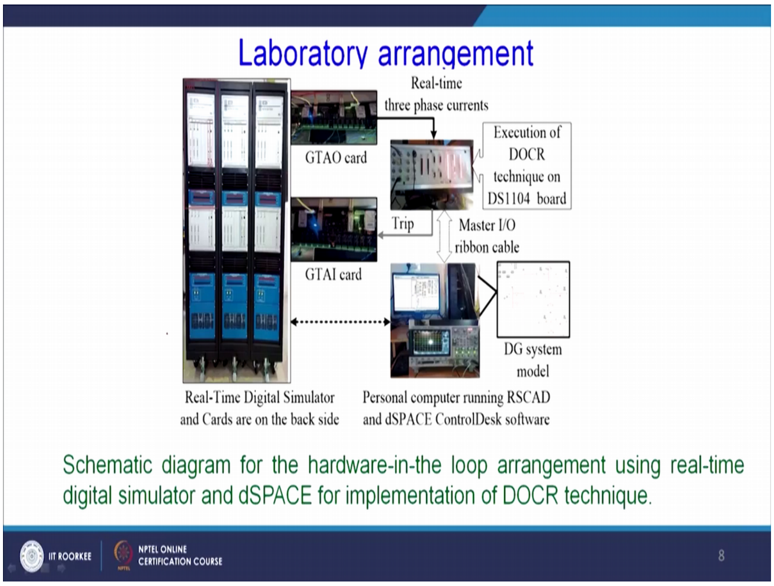

And this the analog signal and there are different types of analog cards. So, using this analog output card we have taken the three phase currents to the dSPACE. This is the dSPACE dSPACE 1 on 0 4 board. And here the algorithm is basically written inside it is bun inside this processor of the dSPACE, and after getting this three phase current signals this algorithm is going to be executed. And after that the trip signal will be sent to the corresponding cycle bricker to take the, I mean the shutdown or trip the basically the DGs or renewable sources.

So, this is what is known as hardware in the loop test bed to test different type of relaying algorithms. This is one of the, I mean few we have simulated many hydro results and we have collected.

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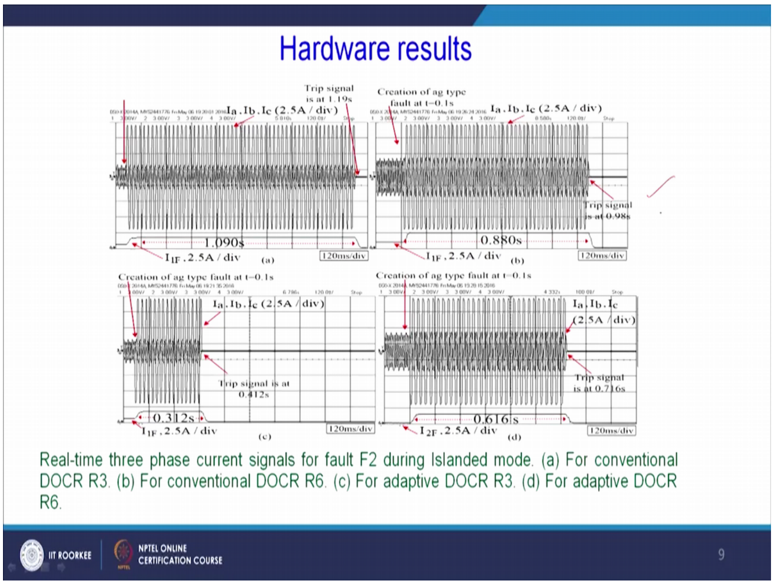

And this is one for example, that this is for the fault F 2 position during islanded mode of operation. And the first figure is for the conventional approach, and the second one is for the adaptive approach the technique what we have developed.

Now, in this conventional approach if you could see here that this time trip signal is quite large. It is almost 1.19 second; however, in this particular proposed approach this time trip signal is generated, within 0.98 second that is one of the advantage it takes less time. And here also if you can see the second one, in this case and the same thing I mean this proposed approach the trip the trip signal is 1.19 second. However, in this proposed approach it takes 0.412 seconds.

So, that is why I mean in hardware platform also we have validated the proposed technique. And it is quite possible because as we are using this sequence component based technique and that studio is based on current information. So, it is a very good platform to implement in real time as well, because whatever the technique we are going to development that should be implemented in field otherwise it has no meaning.

It should be feasible in the practical field. So, that is what this test hydro results tell, because if simulation is not sufficient. We have to test whether this particular algorithm is going to be implemented in dual time or not. So, that is very, very important and if you could design some very fundamental basic techniques based on the information of current voltage, some parameters that is very good because it will be very easy to implement in our digital relaying platform. Now, I will come to another very important concept of this particular adaptive directional over current relaying principle.

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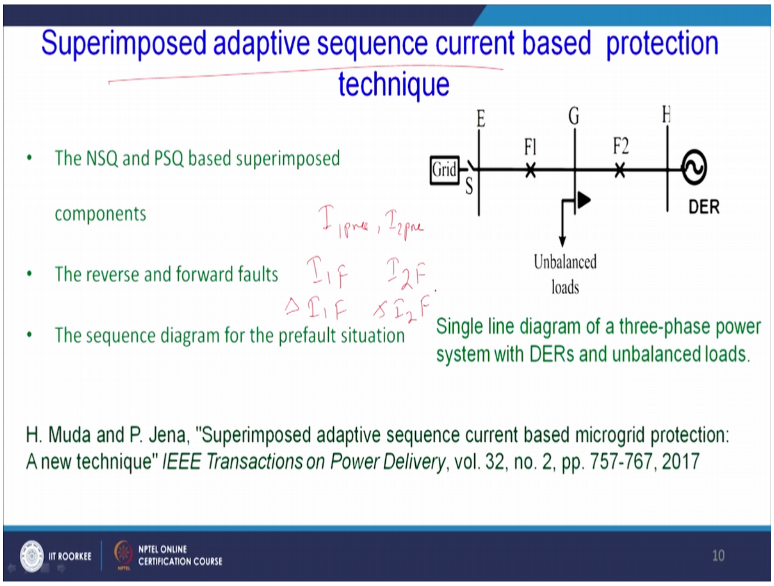

That is based on the superimposed adaptive sequence current based on second method; and if I will just describe a very quickly because already we have discussed many components that what we did in the previous technique. And what is a basic difference between the previous technique and this technique I will just highlight.

In this case more or less we are going to also again depend on the sequence components of the current only. These two techniques are based on only the current information not the voltages information, here we are not using any voltage information, we are just using the current information. In this case we are also dependent on the positive sequence pre fault current and the negative sequence pre fault current.

And again we are also calculating this positive sequence fault current and the negative sequence fault current. And also we are calculating the superimposed positive sequence fault component and the superimposed negative sequence fault component. Here one addition we did here that in this particular technique to distinct difference I will just tell. The first one we did here we have designed one , impact factor why this impact factor comes to the picture, because I just want to highlight here that in our micro grid system we are using different types of renewable source right, so DERS.

Now, what happens if any fault will be incepted the synchronous based DG will supply more than 5 per unit of the rated current. However, at the same time the inverter based renewals will supply the fault current in the range of 2 per unit, within this 2 per unit to of the rated current. So, that is a huge difference I mean you know this inverter based this is clamps the fault current magnitude whereas, the synchronous based DG doesn't.

So, that is a mismatch between the fault current label, that is why this is the main reason that why this over current relays miscoordinate. So, to bring the fault current label to proper order I mean, as I said in the inverter based DG. The fault current is clamp to 2 per unit if you could bring to the right level we can modify or we can just manipulate the fault current again to the right position then I guess of course, we can always avoid the miscoordination between the over current relays, we have tried to overcome this particular problem using the (Refer Time: 19:22) factor concept.

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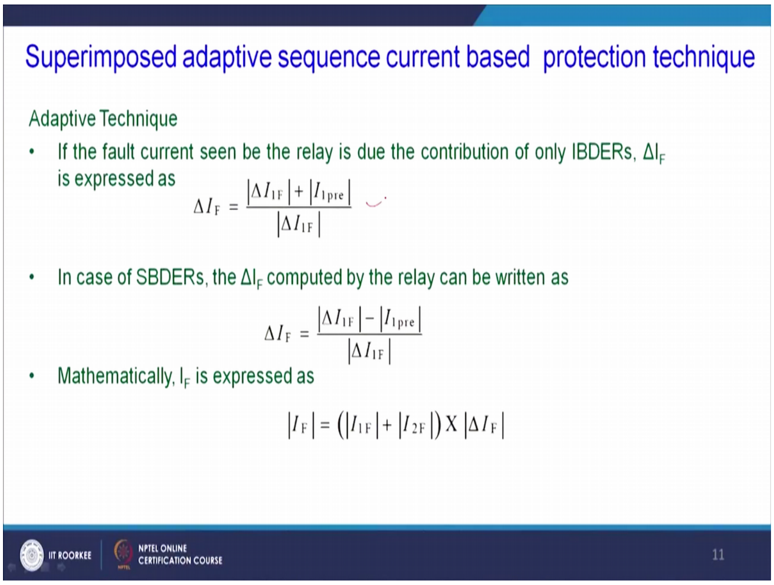

Now, this is one of the impact factor which is used for this inverter based DG. What is that delta I1 F plus delta I1 pre with respect to the superimposed fault current that is delta I1 f. That means, yes of course, the in this case the numerator is greater than the denominator and it will just multiply with the corresponding fault current here after getting this impact factor the finally, modified fault current, see this is important. This I F is a modified fault current, which is addition of this delta I1 F delta I2 F, this positive sequence fault current and negative sequence fault currents summation multiplied by this impact factor. So, that will be my corresponding modified fault current right.

So, that I f will provide me proper coordination between the primary and backup over current relays. Now for synchronous based DGs, we have just reduced the impact factor. So, here in this case this numerator is less than the denominator because we want to reduce the fault current to proper label. So, of course, in sometimes we do in other do in other way around also.

So, and that is case yes of course, in case of synchronous based , sometimes it is also not needed the means impact factor, because its already more than the 2 per 3 per minute, I mean the fault current of the rated current right. So, in this case it is not necessary, but however, in case of inverter based DGs this impact factor multiplication is must.

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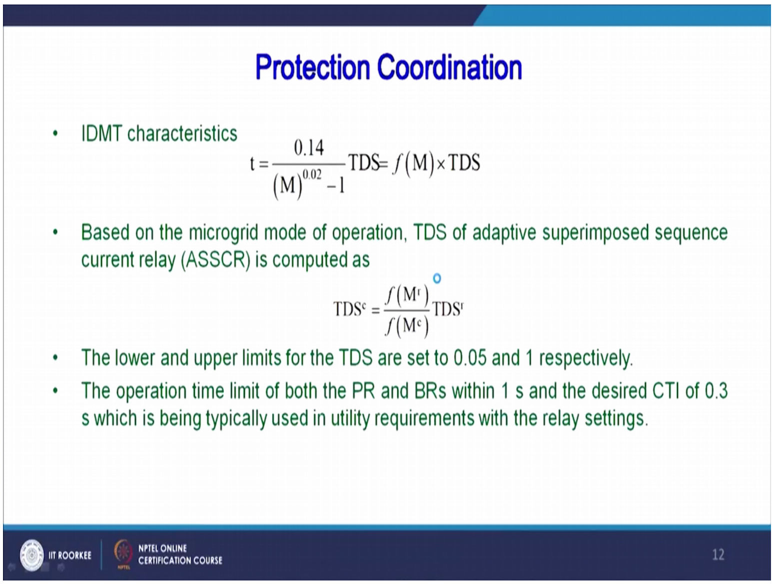

Now, same formula we have I mean the concept we had developed the TDS. Here we have taken the revised TDS the TDS will change as the mode of operation of the microgrid system is going to be changed. And that is what this f M r and f M c and this is the corresponding old TDS and this one is this TDS is the new TDS.

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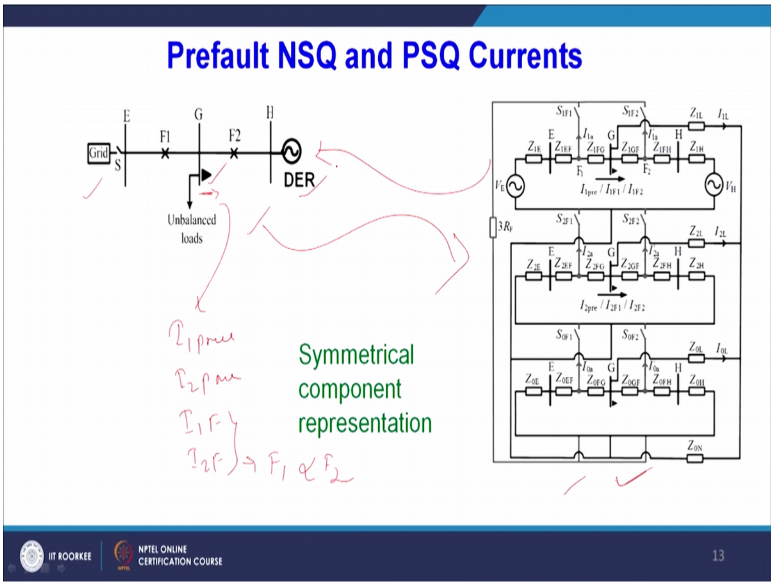

Now, after that we again this particular system has been taken this F 1 F 2 is basically the fault positions. And this is the directional relay and this is the DER the distributed energy source, and this is the grid. And this is the corresponding sequence diagram, if any fault occurs are the F 1 side or F 2 side or there is no fault. So, this particular figure is basically used to calculated the corresponding fault current or pre fault current at the relay location at this point.

At this point we have to basically calculate this I1 pre and then I 2 pre, then I1 F and I2 F and of course, this two fault currents we have to calculate for F 1 position as well as F 2 position. So, these are basically the analysis part and here the corresponding sequence diagram as been discrete, I mean this is the corresponding sequence diagram of this particular system.

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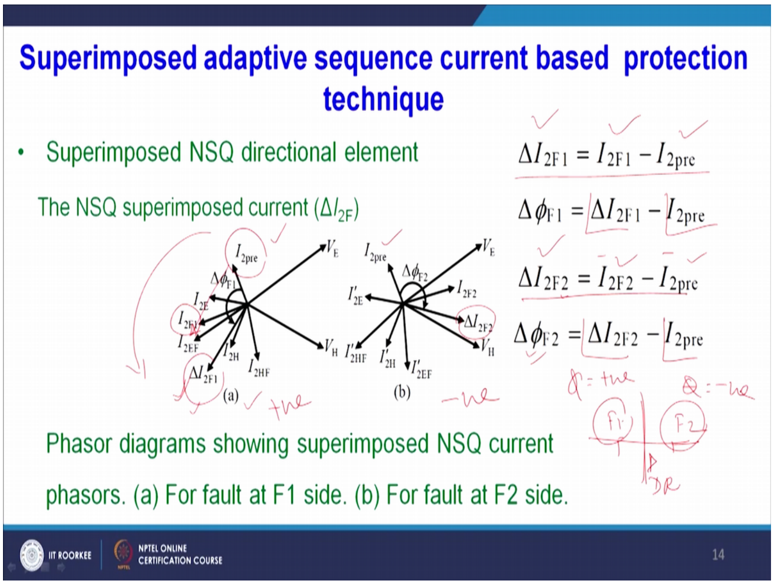

And if you could say after arriving it is observed that this in this particular phasor diagram there are two phasor diagrams a and b. And here you could see this already we have discussed the phasor diagram for the positive sequence based directional element. Here I am emphasizing for the directional element for the negative sequence components. And this is the position of I 2 pre if it is so. And then the corresponding this particular fault current that is I2 F, this is by the corresponding negative sequence fault current position. And their resultant I mean this is the difference and that difference is nothing our superimposed current this delta I2 F.

If I if you will just see I have written here this delta I2 F 1 is nothing. The fault current negative sequence fault current for F 1 position minus the negative sequence pre fault current. Similarly, after getting the superimposed negative sequence fault current, we have to angle between this two that is the negative sequence superimposed current and the negative sequence pre fault current. This angle is basically our requirement and similarly, the next superimposed fault current is basically delta I2 F 2, that is I2 F 2 minus I2 pre.

So, this is the all these are basically the phasor subtraction remember these are all phasors they have with the all the phasor I mean quantities have like a magnitude as well as the angle. Now after getting this superimposed component of the negative sequence for the F 2 position of the fault, we have to find the angle this is delta F phi F 2 is nothing angle of this particular phasor and angle of this particular phasor, difference of this two is basically the angle, angle difference.

After getting this angle what conclusion we will get how to determine the fault current I mean fault direction, whether it is in front of the relay or behind the relay. Now if you could see in this case in the first figure a this is delta I2 F 1 is leading to my I2 pre right. So, that is why as if like this delta I2 F 1 is leading means I mean yes of course, I mean we always in the phasor domain we move in anticlockwise direction.

So, this is leading to this delta I2 pre as a result this angle is going to be positive. Now here in this case if you could see the same analysis we did here, the angle is basically I mean this delta I2 F 2 is lagging to this I2 pre. And this is why this angle is going to be negative and this angle is going to be positive. So, this is a very important concept that if here is my bus and here is my directional relay location. And this is my F 1 position and this is my F 2 position for this F 1 position this phi is going to be positive and for this F 2 position this phi is going to be negative.

So, this is the rule base for the directional relay, now we have validated this particular technique I mean the over current relay this impact factor concept based over current relay and this negative here we have added both positive and negative sequence based directional elements. So, together the if suppose somehow this let us say for positive sequence based directional elements for basically fails for high impedance force high resistance fault case.

However, in that case this negative sequence directional element will help. So, that is why the two directional elements are added together. In case of directional unit and together to validate these techniques we have also taken one system.

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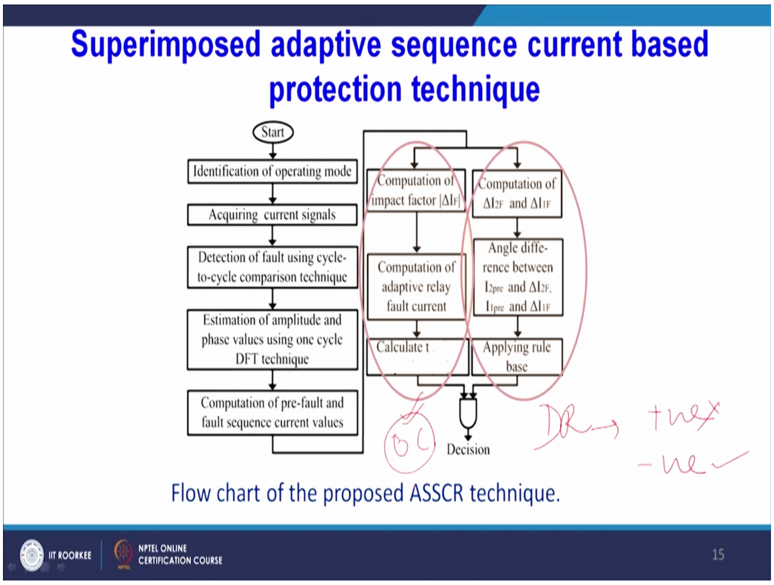

And here the flow chart for this particular technique this side is my over current relay part and this is the directional unit part. And you could see here that the main important aspect of this proposed technique basically this for this particular proposed technique is. It is highly dependent only the current information not the voltage information. That means, we can safe I mean cost wise we are in benefit.

And second point here in the directional unit we have taken positive sequence directional element and also the negative sequence directional element. Any one of fails the other one will helps us to provide the direction. And as far as the over current relay is concerned here we have used one impact factor concept and that impact factor will help you to boost the current fault currents magnitude in case of inverter based TG. And it may also reduce or to bring to proper label, in case of I mean synchronous based TG.

So, that the primary and backup over current relays are not going to be miscoordinated. This is the system we have simulated using this RTDS system that is real time digital simulator I triple E 34 bus system.

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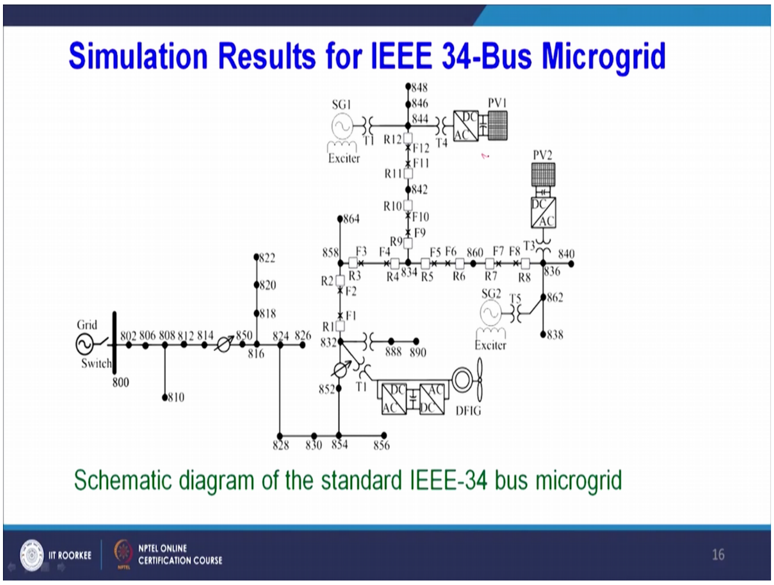

In this system we have taken this PV, this DFIG and synchronous based GI right and this is our grid. And different fault locations you can see here F 1, F 2, F 3 different different locations we did.

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Results for the Islanded Mode of Operation having IBDERs

FP	PR /BR	Ip, A (Mag)	TDS	I_{2F}, A Mag	I_{1F}, A Mag	ΔI_f	t, s	CTI, s
F1	R1	0.160	0.060	0.090	0.320	1.751	0.276	
F2	R2	0.150	0.050	0.050	0.310	1.840	0.230	-
	/R4	0.330	0.057	0.070	0.490	1.132	0.608	0.378
F3	R3	0.300	0.052	0.160	0.540	2.288	0.215	-
	/R1	0.160	0.060	0.070	0.226	1.004	0.560	0.345
F4	R4	0.330	0.057	0.100	0.630	3.510	0.191	-
	/R6	0.300	0.050	0.124	0.448	1.049	0.501	0.310
	/R10	0.475	0.051	0.108	0.662	1.496	0.604	0.413
F5	R5	0.290	0.060	0.080	0.520	2.146	0.279	-
	/R3	0.300	0.052	0.072	0.449	1.059	0.594	0.315
	/R10	0.475	0.051	0.098	0.629	1.033	0.776	0.497
	/R6	0.300	0.050	0.140	0.539	2.271	0.210	-
	/R8	0.890	0.098	0.096	1.131	2.723	0.512	0.301
F6	R6	0.300	0.050	0.170	0.560	2.662	0.183	-
	/R8	0.890	0.098	0.214	1.154	2.617	0.486	0.303
	/R5	0.290	0.060	0.070	0.487	1.649	0.362	-
	/R3	0.300	0.052	0.070	0.444	1.009	0.662	0.300
	/R10	0.475	0.051	0.090	0.626	[illegible].001	0.864	0.502
F7	R7	0.900	0.078	0.487	1.642	0.216	0.216	-
	/R5	0.290	0.060	0.060	0.440	1.087	0.668	0.452
F8	R8	0.890	0.098	0.293	1.620	4.900	0.285	-
F9	R9	0.470	0.073	0.150	0.776	4.188	0.237	-
	/R6	0.300	0.050	0.781	0.440	1.080	0.570	0.303
	/R3	0.300	0.052	0.072	0.449	1.059	0.550	0.357
F10	R10	0.475	0.051	0.104	0.104	3.252	0.200	-
	/R12	0.861	0.130	0.400	1.240	2.953	0.518	0.318
F11	R11	0.850	0.057	0.470	0.060	4.239	0.171	-
	/R9	0.470	0.073	1.487	0.680	1.767	0.494	0.320
F12	R12	0.861	0.130	0.389	1.554	4.732	0.375	-

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And these are the some of results and this is my as I said for the over current relay our main aim is basically to check. Whether the CTI is within proper range or not here, we have maintained within to the 0.345 second and you could see this is proper it is not exceeding 0.5 second.

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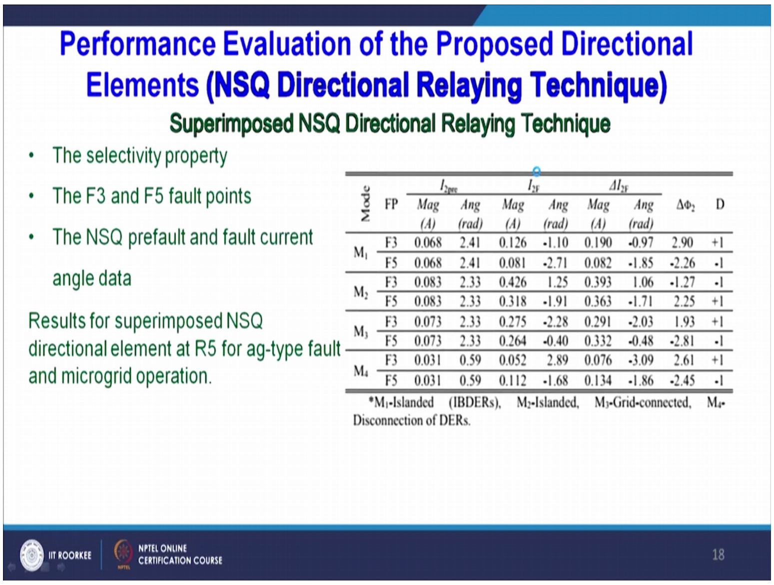

Mode	FP	I_{2pre} Mag (A)	I_{2pre} Ang (rad)	I_{2F} Mag (A)	I_{2F} Ang (rad)	ΔI_{2F} Mag (A)	ΔI_{2F} Ang (rad)	$\Delta\Phi_2$	D
M_1	F3	0.068	2.41	0.126	-1.10	0.190	-0.97	2.90	+1
	F5	0.068	2.41	0.081	-2.71	0.082	-1.85	-2.26	-1
M_2	F3	0.083	2.33	0.426	1.25	0.393	1.06	-1.27	-1
	F5	0.083	2.33	0.318	-1.91	0.363	-1.71	2.25	+1
M_3	F3	0.073	2.33	0.275	-2.28	0.291	-2.03	1.93	+1
	F5	0.073	2.33	0.264	-0.40	0.332	-0.48	-2.81	-1
M_4	F3	0.031	0.59	0.052	2.89	0.076	-3.09	2.61	+1
	F5	0.031	0.59	0.112	-1.68	0.134	-1.86	-2.45	-1

*M_1-Islanded (IBDERs), M_2-Islanded, M_3-Grid-connected, M_4-Disconnection of DERs.

And coming to the directional part also for different fault positions the mode of operation M 1, M 2, M 3 and M 4 also we have diagram here. Here the plus 1 means the fault is back side of the relay and minus 1, means the fault is in front of the relay. So that means, all the I mean the, whatever the techniques we are just proposing, here we can always like tested using the hardware set of process, these are the results for the positive sequence based directional unit.

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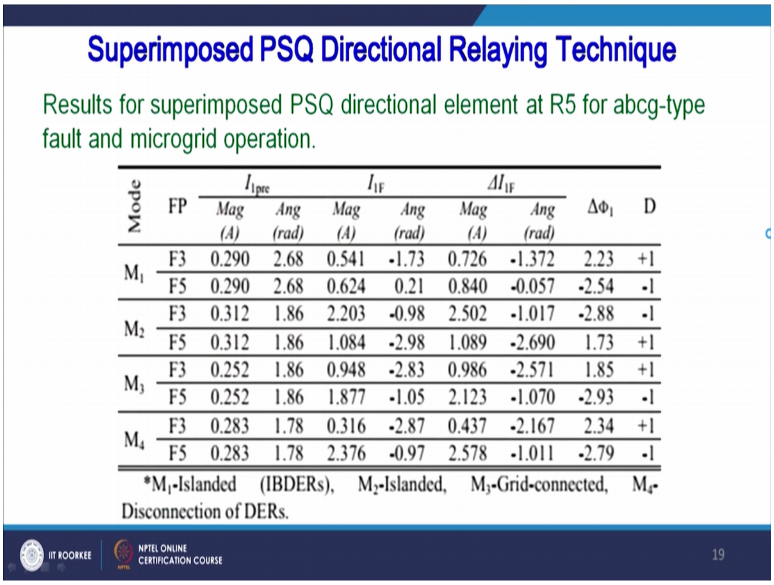

Mode	FP	I_{1pre} Mag (A)	I_{1pre} Ang (rad)	I_{1F} Mag (A)	I_{1F} Ang (rad)	ΔI_{1F} Mag (A)	ΔI_{1F} Ang (rad)	$\Delta\Phi_1$	D
M_1	F3	0.290	2.68	0.541	-1.73	0.726	-1.372	2.23	+1
	F5	0.290	2.68	0.624	0.21	0.840	-0.057	-2.54	-1
M_2	F3	0.312	1.86	2.203	-0.98	2.502	-1.017	-2.88	-1
	F5	0.312	1.86	1.084	-2.98	1.089	-2.690	1.73	+1
M_3	F3	0.252	1.86	0.948	-2.83	0.986	-2.571	1.85	+1
	F5	0.252	1.86	1.877	-1.05	2.123	-1.070	-2.93	-1
M_4	F3	0.283	1.78	0.316	-2.87	0.437	-2.167	2.34	+1
	F5	0.283	1.78	2.376	-0.97	2.578	-1.011	-2.79	-1

*M_1-Islanded (IBDERs), M_2-Islanded, M_3-Grid-connected, M_4-Disconnection of DERs.

And you can see here if the fault is behind the relay this will be plus, and if it is in front of the relay this will be minus 1.

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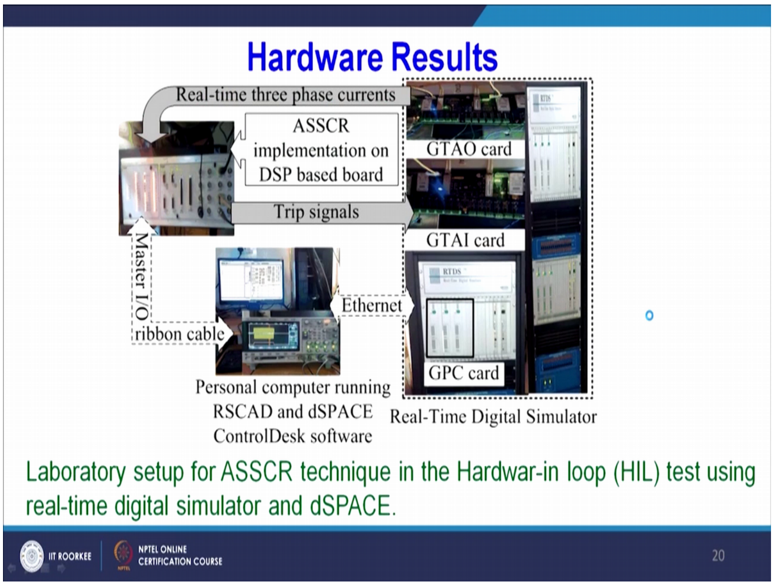

Now, this is the hardware set of already we have discussed the set of and this particular technique is also implemented using this hardware in the loop system and this is the corresponding some test results.

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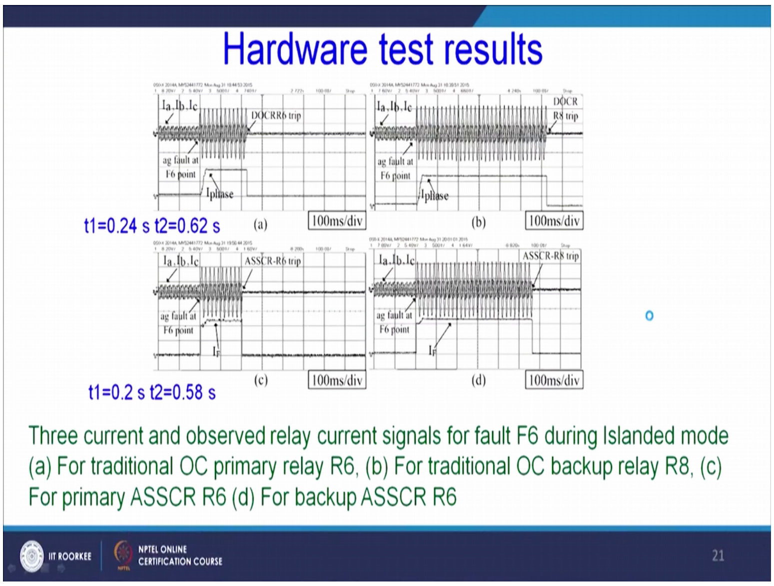

So, the conclusion here is if you could see here that the whole I mean results, we have discussed and I have started like smart grid protection schemes. If you could see the final conclusion is that we need adaptive protection schemes now, because now this microgrid system or the smart grid I can tell this microgrid system is part of the smart grid system.

This smart grid system needs absolutely without any doubt the all the ways the adaptive protection schemes. The conventional fixed mode of operation of the any relays not only this over current relay or directional relay, any relay and may be directional relay we are going to also use this relay.

So, the fixed mode of operation of the conventional technique is going to be I mean operating in nature I mean it will not operate properly, as well as the smart grid protection scheme is concerned. Because, this renewable sources are like solar and wind are very fluctuating in nature that is a first point. And second point is the current contribution during the fault position from different types of DERS also different. And again you know this earlier the distribution network was very radial in nature I mean, now due to the integration of renewable sources this radially is not any more.

So, this power flow or fault direction may be reverse in nature it may bidirectional in nature. So, keeping all this mind it is very essential that this conventional fixed mode of operation of the I mean, this all the relaying schemes are not going to work fine. So, we have to proposed definitely the adaptive protection schemes, in that sense from the site Roorkee site our team like protection group we are trying to have some developed protection schemes for this magnitude system. And we have also this hardware in loop test bed to test all kind of proposed algorithms and may not necessarily this protection also other control strategies as for as the smart grid is concerned

If you could see that now in this smart grid environment this fixed mode of operation of the protection schemes are not going to work out; Because, every time this renewable sources we are going to implement like those are fluctuating in nature. And more over this fault current contributed by different renewable energy sources are different I mean the as far as the magnitude is concerned different, if you could see the inverter based DGs basically clamps the fault current to 2 per unit of the rated current. And also these synchronous based DGs basically provide 5 per unit of the rated current I mean the fault current magnitude.

So, in that sense this is also one of the concern and one more concern basically if you could see that in distributed energy sources our smart grid environment. If any fault occurs the fault direction reversed I mean, the bidirectional fault current takes places. I mean the power flow in now bidirectional instead of unidirectional. Earlier the distribution network was radial in nature, but now due to the integration of these renewable sources this radiality is not any more.

So, that is why these are the different concerns and we are also proposing the demand side managements different new concepts as far as the smart grid is concerned. So, that is why this fixed mode of operation of the protection scheme is not any more I mean going to work. So, that is why this adaptive protection schemes where to be set.

Thank you so much.