Economic Operation and Control of Power System

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Hello and good morning everyone, welcome you all for the NPTEL online course on Economic operation and Control of Power Systems. So in the last class we have discussed about advanced distribution management system ADMS, so we will continue with the rest of the part of the ADMS discussion. So we had discussed little bit about SCADA system, so what is SCADA? SCADA is Supervisory Control and Data Acquisition. What are the key merits of SCADA? It is a industry preferred choice, many industries like ABB, Schneider, Siemens, Hitachi all these industries they prefer to have SCADA as a control automation tool to administer what is happening in the distribution system and also to control and take appropriate action at a given point of time. And it helps to remotely control and monitor the renewable energy sources as well because the distribution system also there are many renewables being scaled up. So it also helps to forecast renewables, monitor the real time operation of renewable energy sources and also to control it.

Hence SCADA forms the closed loop system, you collect the data, process it, analyse it and then take appropriate actions, so thereby makes a closed loop system. It works with very less human intervention because wherever there is a human to error is a human right, so there will be some errors. So because power system requires accurate administration and control action, so wherever there is human intervention there is a possibility of error to take place. So SCADA helps us to minimise the error in that regard and it also helps to monitor the entire system in real time and ensures the voltage and currents are within the limits.

So the voltage, currents, the frequency if there are in the limits the system is working in a stable operation that is what we always aspire for. So what does SCADA offers for? As I discussed you can see here the data flows in this direction and the control flows in this direction. So you will be receiving the analogue input data, the current, real time current measurements, voltage measurements using CTs and PTs and all these potential transformers and then with the RTUs this data has been connected and further processed using IEC 61850 protocol that we have discussed. So data acquisition, status, alarm sequence of events, analogue data, accumulated data, so you store the data, you receive the data and store them. At the master station there will be some control logics, flow charts, algorithms being put up.

So as per the condition of the system and requirement of the system an appropriate control signal is been issued to the converters, to circuit breakers, to the tap changing transformer, to the capacitor banks and all these devices. So the control action flows as I told it goes in this direction, so like trip or close of a breakers, start or stop let us say if there is a lack of power supply and the main grid is failed, you want to operate the system in isolated fashion. So there will be some converters which will be operating in grid forming mode, there will be some converter which will be operating in grid feeding. So I mentioned here grid forming, grid feeding and also there will be some converters which may be operating in grid supporting mode. So and you may require at some point of time just to give the voltage support or to have a backup, let us say the renewables are not there.

So maybe diesel generator may be kept though it is not recommended for some emergency scenarios diesel generator may also be kept for backup. So you may ask the diesel generator to turn it on. Hence set point values for the batteries and the converter settings all the set point values can be decided, the tap changer, transformer's position can be decided whatever the control action that you want to take. So the control action will flow in this direction. So SCADA offers a distribution control for substations, feeders, inter-type points, distribution equipments.

There will be sequencing of events like you know once the relay is been sent, relay is triggered there is a circuit breaker action and owing to that if there is a converters that may be pitching and they may be asked to form the grid. This there is a sequence of events being administered and also there is a time stamp data. This is one of the key feature of a SCADA system. At a given point of time let us say any data that is recorded that is with some specific time, specific time duration. Let us say now the time is let us say 12 o'clock and the date also it will be mentioned DDMMYY format the date, the time, everything is very specifically mentioned so that anybody would get later words if they want to analyze what action being taken.

So they will get go through the data, the time stamp data then they will get to know okay this is the kind of event being taken place at this point of time so then this is a control action being carried out at a specific instant of time. So this is very important aspect and there is also outage analysis. If there is a fault or if there is a disconnection of a line then you will get to know for what is the main reason for the disconnection based on the data being collected. So outage analysis being carried out and demand response. So if there are multiple customers and you may ask them to you know you may invite them basically to participate in demand response so that you can maintain the flat load profile or you can also help to reduce the stress on the system while you provide incentive to the prosumer in return.

So demand response is a very important aspect for future IDMS that we are looking forward for and there is also web access for operators. So the operators would get to know we have discussed about the bird view of the entire system the HDMI vision of what is happening in the system. So there is a clear display or indication of what is happening in the system for the operators perspective. So fault location, isolation and service restoration. So objectives are reduce outage time to the end customers, distribution automation application, minimize the network losses.

So as we have mentioned you know you do not want the customers to suffer for a long time due to any reason without any power supply. So if you reduce the outage time that is what the customers want reliability should be very high and minimize the network loss. So as we have discussed you know many states have distribution system losses, transmission losses will be also there. So how much, if you can reduce loss to certain percentage even 0.1 percentage of reduction loss can save a lot of money actually, lot of energy saving can happen.

So minimize the number of overloaded elements because if you stress the devices what will happen is their life would get degraded and the breakdown point may happen well before the given life span of a specific device. So it's always better to operate any device at a sweet spot and not to exceed the beyond capacity or not to under operate so the efficiency would be also very less and maximize the average voltage. So voltage profile should be also very appropriately managed and steps in fault location, isolation, service restoration. First as it is clear to all of us locate the fault then isolate it and then capabilities estimation can happen and then service restoration. So locate the fault, exact location of fault, identification very important then isolate it that segment of fault location itself the segment and then help to restore the system as quickly as possible.

So this is what is the isolation sequence that is also been displayed here, fault location and time of happening occurring of fault is being monitored and then fault isolation for multiple fault locations there could be fault happening at multiple places that need to be isolated and optimal service restoration strategy and results of new switching positions and overall network impact so that can also be administered. So there are three fault location isolation service restoration architectures. So the first one is centralized FLISR. Here the each relay communicates to control center directly. There is one control center master station where individual relays communicate one to one communication is happening.

It requires a very high bandwidth communication network. So the cost would be high and there is also a chance of cyber attack and breakdown of communication channel, failure of communication channel. So there are some issues with the centralized system. So but you know you get to know the information on a frequency based updates. So there is another approach which is decentralized fault location isolation service restoration.

So here the system is deployed at substation level using a single or a redundant automation device installed in each substation faster with lower bandwidth requirements because it is decentralized so the bandwidth requirement would be very less and it is deployed at individual at each and every substation. And then there is a distributed FLISR. This uses control devices at each switch or recloser locations. These communicate among each other to determine where the fault has occurred and to determine the appropriate switching actions necessary for the restoration. So actually distributed FLISR lies between decentralized and centralized and it enjoys the advantage of both decentralized system and centralized system.

It is more appropriate or preferred choice against either of them. And then the methods for fault location. We have apparent impedance measurement. So we have seen the impedance relays and this more relays and also what they exactly do is find out the impedance basically exact impedance. If the impedance is less than the given impedance you know impedance there is a boundary if the impedance is very less as compared to the nominal impedance or working impedance of the system.

So if this impedance is less than naturally the fault is there is some high current being flowing into the system. That means there could be a chance of fault. So but the challenge with this apparent impedance measurement is in real time because if there is inverters placed in the system and inverters will also try to inject they also try to support the fault. There is a continuous flow of fault current may happen and exact impedance measurement is a quite challenging task. So direct three phase another approach is direct three phase circuit analysis.

Then we have superimposed components, travelling waves can also be used, power quality monitoring data, artificial intelligence and machine learning based approaches where you know get to know you train the neural networks collect the information and then try to analyze the exact location of the fault. So there are multiple means and it depends upon the user to adopt a particular thing based on the cost and the accuracy of fault location that need to be the amount of accuracy one decides to have is also a matter of thing that need to be considered. So then need for reconfiguration. The next study is apart from FLISR so there is a need for reconfiguration. Depending upon the current loading conditions reconfiguration may become necessary in order to eliminate overloads on specific system components such as transformers or line sections.

In this case it is called load balancing. So basically you know specific feeder if it is getting overloaded or due to any reasons and the transformers may also get overloaded.

So if you can change the configuration of the network maybe tie lines, maybe switch, maybe added so in that case you know try to reduce the burden upon specific portion of the network and improve the efficacy as well as the life span of the system as well. So for reducing real power losses in the network this is another advantage that one can look upon reconfiguration can be done. This is usually referred to as network reconfiguration for loss reduction.

This is specific objective and to maximize reliability of the system during line outage or schedule maintenance of line. So during normal condition the goals are minimization of loss, reliability improvement and load balancing whereas in the case of fault condition it is isolation of fault line maximum service restoration. So these are the motivations to go for network reconfigurations. So process for offline reconfiguration, read the input data, read initial status of switches before reconfiguration, then perform load flow, find the total power losses for above initial state, then permutation commutation, find all possible configuration such that the system is radial and all loads are connected. So check out what combination of, what permutation combination of the network would help us to you know reduce the loss because we again go for load flow once for each combination again go for load flow then calculate power losses reliability for each configuration and whichever gives the least power loss or the maximum efficiency and reliability one can think about considering that option.

And then the another useful study is unbalanced minimization in distribution systems. So you can see here in this waveform you can observe that there is unbalance that means all the three phase are not equally loaded. So unbalance in the system increases mostly due to the following reasons. One is increase in number of single phase loads because though actually we will try to connect or balance the phases, connect loads such that the all the three phases at any given point of time get to get an option get an opportunity to supply same amount of load, but it is not in our hand. Let us say I mean if there is a specific feeder where there is equal amount of load being distributed to R, Y and B phase.

So some of the customers are they have gone for some vacation and the connected to R phase let us say. So it is not in our control. So the Y and B phase would have to supply the loads which are connected to them. So thereby they increase the unbalance actually. So connection of sources in single phase modes this is another reason and due to the uncertainty associated with them.

There are some home loads upon which you know there is also solar backup supply. So what is happening is if there is a smart meter either they choose to feed the power back to the grid or they may try to use them within their house itself. So in the either case there would be reduction in the load consumed as seen from the distribution system side for that specific customer from the transformer perspective. So there will be uneven loading anyway in the distribution system and not only that uncertainty due to load such as electric vehicles. So electric vehicles is a kind of disguised storage.

So it can either go for charging or discharging at any given point of time. So thereby it may change the load pattern of that specific phase and due to increase harmonics because you are bringing in lot of electronics converters both for solar PV or for the electric vehicles there will be converters in place. So they also bring in harmonics if the harmonics are being placed and depending on the sort of harmonics one there could be some disturbance in the system and voltage drops can be very high due to unbalances which is an unwanted scenario. Not only this there will be single phase motors multiple reasons why this unbalance can exist and it will continue to exist. Distribution system it's not so easy to balance the phases.

So another approach one can think of is bringing storage system. So I was discussing with some industry partner and they were recommending to have let's say if there is a distribution transformer there is a distribution transformer this is a distribution transformer and I am just for the easy of analysis I am just splitting it into three phases. So this is let's say R phase, Y phase and B phase just for easy analysis. So then if there are loads being connected across them and these loads are variable loads. As I already mentioned at any given point of time R phase load, Y phase load, B phase load may be different.

So what one can think of is to keep a battery let's say you know primary side there is a storage device let's say through some converters. Through some converters you know this is storage system battery energy storage system with converters I just mentioned like this. These are converters and this is connected to the transformers similarly for all the phases. So what one can think is if you can give some command to the batteries because there are converters being placed. So you sense the unbalance in the individual phases let's say these two phases are overloaded compared to R phase, phase B and Y they are overloaded.

So what we can do is you use the battery converter of R phase because you have to balance the system if there is sufficient sort of SOC limits are not crossed then you can also charge the battery at R phase which is connected to R phase. So that you also bring this R phase loading equal to Y and B phase. On the other hand the other option could be let's say if you want to control in either on the other side B and Y phase the batteries are connected. So what you can do is try to increase the discharging of this battery so that you can reduce the burden on the transformer so that R Y B phase from the transformer perspective that doesn't seem to be overloaded. So one can think in any direction based on the placement of battery on primary or secondary side one can look at various options so that you can try to reduce the unbalance in the system.

So there are other methods measuring power consumption at a bus across the feeders and switch the loads, use transformer switches example three phase inputs single phase output static transfer switches, individual monitoring and centralized control is involved, requires smart meters, central controllers, good communication network, hardware switching device. So smart meters are very important because real time you need to measure what is happening at the load side and there could be some master meter and then you can take appropriate action. So control of inverter based schemes, so requirement of centralized control, communication and switching and load balancing can be reduced if smart inverters can be involved for unbalanced minimization. Smart inverters which are participating in volt work control can be extended to reduce unbalances too which can increase the performance in a dynamic environment and smart inverters are quick and flexible this can reduce the burden on network reconfiguration scheme which can even be slower in time frame. So what you can do is use these inverters so and then let's say the PV inverter is there, this PV inverter can also be used to reduce the unbalance in the system right.

So if the same PV inverter which may be creating problem of unbalance as we have discussed in the last slide that inverter if the capacity is available so can we provide some damping using that inverter, damping control can be brought in or if there is a battery can be connected across it try to reduce the unbalance. So as we have understood the unbalance factor this is negative sequence by positive sequence right. So what we have to do is reduce the negative sequence, unbalance if it exists then the negative sequence would be there. So negative sequence current need to be minimized. So there could be some negative sequence controller, negative sequence controller so which can help to minimize the effect of unbalance in the system.

So this is what we can do with the help of inverters as well. So smart inverters are capable of rendering this support. Then load forecasting and model development. So collect the historical data, load data and load shading data right. So when at what point of time you disconnected a load, you collect the historical load, prepared unconstrained data, collect historical weather data and then collect historical event data because loading will be happening based on certain situations and time, place and circumstances ultimately.

So if there is a festival, if there is a cricket match, if there is a football match, if there is a election, so as we have discussed in the beginning of our lecture also that due to all these reasons and temperature variations so there would be variation in the load. So you collect the historical data and analyze the data, prepare a model. Ultimately we need to prepare the model. So you collect suitable methodology to prepare the model, find the data and tune the model, select the best model and implement, run and refine the model. So basically use the previous data, try to understand for a specific location what could be the load model looks like and then to that load model you retune it and maybe you can use artificial intelligence also.

So modeling can be done in this fashion, just physics based modeling or AI based modeling you just consider it to be a black box and put lot of data and try to you know have a curve fitting based approach and then there is third approach which is AI plus physics based modeling, AI plus physics based modeling. So what I suggest is you know either physics or AI based model have their own considerations and constraints. AI plus physics based model, so that could be the future scope actually because the load model keeps varying as the presence of many electronic loads and EVs, the load dynamics are keep on varying. So you need support from artificial intelligence. Also there should be physics or science behind it, how exactly the curve fitting can be done.

So based on this one can prepare the load model then so that you can forecast it in a future okay this date and time, this could be the possible load based on the historical data and the temperature forecast. So one can think about load modeling as well. This is one of the important features and expectations from ADMS. So with this we will conclude for today and we will continue with the rest of the ADMS part in the next class. Thank you very much. .