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 System. In today's class, we will discuss about a very important topic which is Advanced Distribution System Management or we also call it as ADMS. So an overview of today's discussion, we will be discussing about the introduction part of the ADMS, ADMS architecture, the functionalities of ADMS, application of ADMS, basics of ADMS and product of ADMS, ADMS technology in trend and ADMS network model and finally the ADMS case study in India that will cater later words. So ADMS introduction in the past few years, technology has advanced at a very fast rate but even today most distribution system rely on old technology. So there is, though we speak about advancement in the technology but that is not yet been reflected in the physical system, the distribution system as we see today in most of the countries.

So breakers to disconnect the line in case of any fault, customers to call in to report an outage, line queue to find the affected circuit and restore the power. This is what we see in day to day life. This takes a lot of time and manpower, thus several utilities are implementing ADMS that is Advanced Distribution Management systems. So you do not want manual intervention in the case of system faults to restore or if there is a system fault and subsequently if the system has to be restored, so you do not want manual intervention to happen or this will inherently consume lot of time and system restoration will get delayed.

So ADMS functions are being developed for electrical utilities that include fault location, isolation and service restoration. It is famously known as FLISR, Fault Location, identify the location of the fault accurately, isolate that part of the section which is subjected to the fault and then help the system to restore itself in a very quicker manner. And also the another important functionality of ADMS is volt, volt ampere reactive optimization, the conservation through voltage reduction we call it as CBR, peak demand management and support for micro grids and electric vehicles. These are some of the important features of ADMS. We will discuss them one upon another as the slides proceeds further.

So ADMS is a software platform that integrates numerous utility systems and provides automated outage restoration, optimization of distribution grid performance. So ADMS is an integrated platform for enhanced operation, outage management and delivery optimization. So as we speak about economic operation, so it also includes how effectively utilize the existing resources in the distribution system to optimally engage them in different operating scenarios. So this is how a typical architecture looks like. So this consists of basic features and the advanced features.

The basic features include static view of network configuration, network operation which includes switching orders, crew calls and others and customer status calls whereas in advanced features we have supervisory control and data acquisition what we call it as SCADA. So SCADA features will be there and outage management prediction analysis. So can we predict the possibility of system being taken out and network visualization tools, power flow analysis what we call it as load flow analysis to consider the health of a system whether the whether is there any limitations being violated like thermal capacity or the voltage limits of a buses. So just to understand that if line losses are within the limits and all these features can be seen in the power flow analysis and also the network optimization as we as I have already told. So how effectively we are going to utilize the existing system components to ensure the effective and efficient operation of the system.

And then so ADMS acts as a catalyst to transform the grid. So it is a head to head comparison between the conventional or traditional grid and the transform grid with the ADMS in place. So the conventional grid is manually driven, distribution management and optimization is manually operated mostly whereas the system the transformed grid with the ADMS features is a system driven distribution management and optimization and automatic outage restoration is seen in the case of transformed grid whereas there is a manual outage restoration that is seen in the case of the traditional grid. There is no optimization features in the case of traditional grid whereas there is optimization of the performance of the entire distribution grid and lacks operation visibility in the case of traditional grid. So because the monitoring aspect is very poor, the control action is very minimal.

So this is the limitation of the traditional grid whereas as you can see in the case of transformed grid, predictive simulation and automation operation and operation visibility is quite good in the case of transformed grid with the ADMS features. So just overview of what ADMS can give to all of us. It is the bird's view, bird's eye view on the entire network. If you want to visualize what is happening in the system, a bird's eye view can be seen in the case of ADMS installed distribution system. So synchronized model across all applications because so we will be getting time stamp data.

So we will get to know about the model features of the entire distribution system. Once we have the modeling aspect clearly visible, so then we can able to carry out various analysis and it is also facilitate historic real time and forecasted data for better analysis. So data monitoring, the control and operation is very much possible in the case of ADMS based distribution system management and faster outage response. If there is an outage, how quickly you would engage your existing system components so that you can able to restore the system as quickly as possible that is that is the main objective of this ADMS as well and then also the mobile workflows. So effective utilization of the workforce can also be visualized here.

So what are the financial benefits? Of course, this course deals with economic cooperation. So we need to look upon the financial aspect as well. So money saving by using ADMS you can see here. So without ADMS, it is improper demand planning. So you will not be able to visualize that exact demand in the forthcoming hour.

Of course, the demand forecasting will be done, but you will not be able to control the demand. So demand side management, demand response, the interaction with the demand is very poor in the case of the conventional system and improper topology processing. Whereas in the case of with ADMS, there is proper demand planning, correct topology processing and power of data and ILS is seen. So as you can see here centralized operation, unmanned substation, bidirectional communication, fault location isolation and service restoration and self-healing of the grid. If there is a fault, grid itself can able to heal the problem that grid is facing at that point of time and switching optimization, field crew management, all these are very effectively being taken care.

So it would reduce the operation and maintenance cost. So what we call it as O&M. O&M cost is a very important thing. So that also constitutes to the overall the financial requirement of a system. So that is being well operated in the case of ADMS based system.

So as you can see here, these are some of the key features. AMI or Advanced Metering Infrastructure and METER Data Management System. So with the help of smart meters, so actually the whole world is looking forward to install the smart meters, replacing with the conventional energy meters. When there are smart meters being placed, so you will get to, the utility will get to know the real time information of what is happening at the load site and METER Data Management System. So there is a big collection of data, how do you manage this data such that you know suitable features, signatures can be taken out such that you know appropriate action can be taken into place.

And cyber security for operational technology. Once you bring in the communication layers to make system more observable, there is always a cyber threat. So how do you manage cyber security while you carry out advanced actions, advanced features being

executed. So that is the key objective as well. And then artificial intelligence and big data analytics.

As I already mentioned, there is lot of data being accumulated. There could be so many junk data. So how do you manage this big data. So that is another important tactics and artificial intelligence certainly play a very crucial role as we can see that if there are so many data, so the data handling also require AI support and also forecasting of renewables, forecasting of load, AI can have a, can give us a good backup as well. And there is an ancillary service feature.

Suppose you want to participate in the reactive power management as well as the harmonic minimization. So these features can be inbuilt into the ADMS features as well. And if you want to have a secure operation, suppose you want to have a peer to peer energy trading, you have a surplus amount of solar energy at your home and you do not want to you know feed it into the grid, rather you want to support your neighbor. In exchange you may expect some financial support from your neighbor. So this peer to peer energy trading can also be carried out with the help of blockchain features which could be part of this ADMS as well.

And then moving forward, so what are the driving forces to have ADMS adoptions? So one is resiliency. As I already discussed about this that you know the system may be reliable, but it does not ensure that the system is resilient. So resiliency means how best the system can able to support the critical loads or the emergency loads in the case of extreme events such as if there is a fault in the system, the system being isolated or if there is a natural disaster, how best the system is resilient. So the ADMS also help us to improve the resiliency of the system, the ability to withstand or recover from a natural disaster quickly. So is what resiliency is all about and the ADMS can support this as well.

And the renewables, you can see here the ability to accommodate larger quantities of distributed energy resources. So can we penetrate as many renewables as possible having in place ADMS features and then replacement, the ability to supplement legacy systems that are unable to integrate new technologies for which the staff can no longer provide support. So there are so many old legacy devices like you know transformers and all these devices. So can we able to monitor the health of this device and ensure that what time is more suitable for their replacement, the circuit breakers, the OLTCs and the capacitor banks and all these legacy devices. So apart from this the regulation aspect, ability to accommodate changes that encourage reliability and efficiency.

So both the from the utility perspective as well as from the consumer perspective, so can we able to bring in suitable regulations such that they can support each other and to and thereby help to support the system. And safety, this is another important feature of

ADMS. So managing field crew work and public safety as well. So typical distribution network, this is a schematic that we have taken from the literature. You can see here there are solar, so this is connected to boost converter.

Boost converter will help to extract MPPT and this is connected to a DC grid. So we also have a battery. Battery is meant to give the energy backup. So suppose this DC grid to which this solar PV, the battery is connected, there is also I guess some DC loads being connected to the DC grid directly. You can see here there is also a DC load being connected.

So there is a DC load, there is a solar PV, there is a battery being connected to this DC grid. Even if there is a disconnection, from the AC grid or the main grid, this is your main grid. Even if there is disconnection, so still this DC microgrid what we call it as can able to sustain the DC load. So with the help of solar battery, solar and as well as battery. And apart from this, there is a voltage source inverter, this is a bi-directional inverter which will help to exchange power between the DC grid as well as the AC grid.

And there are, the AC load is also part of the AC grid and there is the distribution system being connected to the AC bus side. So in a nutshell what we have, AC and DC loads, renewable energy sources, storage devices, protective devices and converters and microcontrollers to control these converters. So the centralized energy management approach, so you have energy here right. You need to manage this energy. So it would get real time information with the help of sensors.

So the output voltage of the PV panel, output current of the PV panel such that you can track MPPT. So there is a battery current, battery voltage such that you can administer whether it is a time for charging or it is time for discharging and there is a grid voltage so that you can connect and synchronize with the grid. And if there is a requirement you can exchange power with the grid as well. And there is a associate of the battery all the time you want to ensure that the state of the charge of battery is always within the limits, the circuit breaker position and all the powers being supported by the converters and the DC-DC converters as well as the inverters. So having in at the real time if you get this all inputs, so centralized energy management approach which is one of the feature of ADMS would look after what action to be taken at appropriate time such that both the financial and the technical benefits is being achieved.

So integrated ADMS typical architecture, so there is a real time network, this is a real time network and there is also the enterprise is a financial aspect. So you can see here there are IoT is being connected, feeder automation, substation automation, as I discussed energy management system, microgrid controller, automated fault analysis, interactive voice response and all these are part of real time network you get the information, there in IoT based devices are there. So and the ADMS also consists of the financial aspect that

means the work order, the AMI or MDM, metering information, send the network model management, energy market aspect like you have a distribution system, how do you, what time you purchase the power and how do you sell it and all these things. So enterprise asset management is also important aspect and enterprise resource planning. So there are some certain resources which are meant for steady state operation, certain resources which are meant for transient operation, how do you plan your resources to be taken into action at appropriate time.

So you can see here ADMS consists of these things DMS the distribution management system, the outage management system, ERP that is enterprise resource planning, work management that is what is ERP, visual reporting, SCADA and all these features. So this is how a typical ADMS architecture looks like. The functionalities of ADMS online diagram you can see there are model, analyze, monitor, operate and optimize. So in the case of modeling you have online diagram, protection diagram, the logic diagram, control circuit schematic, cable pulling you know the cable layout how do you draw the cabling, how do you layout, how do you put up the cables such that the cable may not get damaged, the cable pulling is layout will be taken out taken into consideration and substation grounding is also is one of the important aspect of modeling feature and there is analysis per aspect that means distribution system state estimation which we have dealt already, the load flow analysis, fault calculation, reliability analysis. So these are the analysis part of the ADMS and there is a monitoring so that means telemetry, alarming, reporting and trending.

So you get the real time information from SCADA, RTUs and the smart meters, the PMUs. So once you get the data you analyze them and if there is any suitable action to be taken that can be reported or an alarming event can be generated. So apart from this the fault management, switching management, load shedding these are the key operation principles of the ADMS. And what do you optimize? The volt-var optimization, the pre-configuration, short term forecasting and the demand response.

We will discuss about these aspects as well. So ADMS for analysis operation of all level of electrical infrastructure. So you can see here at the generation station there is a production of electricity, you step up the voltage such that in an efficient manner you can transmit the power over a long distance. There is a transmission line with 765, 500, 345, 230 or 138 kV voltage and there is a step down transformer at the receiving side where you cater to the need of primary and secondary customers. So these are the primary and secondary customers and there will be industrial loads as well. So having ADMS in place there is an all round overall improvement in the operation of the power system.

So smart visualization for smart operation. There should be smart visualization in order to carry out smart operation, right. So this is how the visualization aspect of ADMS looks

like. There is an online view. So the real time online view is there and then there is an alarm event. You can see here there is a generation of alarm signal.

If there is green means you know the system is healthy or if there is red means it is a critical event so you can create awareness in the system operation and there is a SCADA high definition of multimedia interface, HDMI feature is there. And there is a web based dashboard where you can see the real time meter updates like current meter, ammeter, voltmeter and energy meters. These are being put up in the visual dashboard so that the system operator can have a real time visualization of what is happening in the system and there is a network view of the update on the line flows and there is a geospatial view actually. One can have a bird view of how the system is look like at a given point of time. So this is what smart visualization of ADMS based system looks like.

So what are the typical application of ADMS? Switching optimization, feeder reconfiguration, volt var optimization and control, conservation voltage reduction, load allocation, fault location isolation and service restoration, switching management, demand response and fast load shedding. So these are some of the key applications of ADMS. So ultimately you know all these features are very much relevant in the advanced distribution system. So basic DMS basics of DMS function, distribution system state estimation. So you will get to know whether the meter is functioning properly or not, network connectivity analysis, load flow analysis as I have discussed about this.

So intelligent load shedding and restoration, forecasting and distribution networks, load balancing via feeder reconfiguration and topology analyzer as well. So state estimation measurement devices and tools include topological processor, CT, PTs, relays, network parameters like the impedances and remote terminal unit which is part of a SCADA system and typical techniques like weighted least square method Kalman filter as we have discussed the state estimation takes you know takes input makes use of these tools. Challenges, measurement arrive at different time, need a good statistical technique, cyber attack and large number of bad data can also create some trouble there. So network connectivity analysis, the extensive process of connecting various parts of a network to one another operate with the help of meter data in real time. You can see this distribution system load flow analysis, the famous one is forward and backwards sweep algorithm which has current summation methods, power summation methods and admission summation methods of analysis and then distribution system load flow analysis also include compensation methods, implicit Z bus Gauss method, modified Newton like methods, miscellaneous power flow methods.

So these are the typical load flow analysis being adopted in the distribution system and volt work control. The objective is to active loss minimization, load demand reduction, weighted sum approach, controls, you make use of the capacitor banks, make use of the conventional legacy devices, OLTC, voltage regulators, smart inverters and use them at

any given point of time such that you know they are most effectively utilized and also there is enough reactive power reserve being achieved for the emergency situations. So the constraints if you take care of, if you consider the mechanically operated conventional OLTC there is a restriction on how many tabs that it can operate and similarly in the case of capacitor banks as well the voltage magnitude across the feeder should not be violated at any given point of time, inverter operation limits, the current carrying capacity of the inverter there will be some limits so it should be taken into consideration, storage state of the charge that is associate of the battery is also being taken into consideration. So smart meters for the data inputs, load profile, real time, voltage, current and power factor are being updated. So volt power optimization could be multilevel is offline plus real time and by using smart smart inverters as well.

So this is one of the important aspect of this volt power optimization, this conservation voltage reduction. So what generally people would do is if you have to reduce the demand at a given point of time, so reduce the voltage operation voltage such that if the voltage limit is, voltage is being considered at a given point of time such that it is operating at a lower limit. So there is a upper limit and the lower limit of any bus. If you are operating at a lower limit, so still you are within the limit, you have not crossed the limit. So if you reduce the voltage naturally the power consumed by many devices would get reduced so that you can manage the existing power within the existing resources such that the power balance may be taken into consideration.

And apart from this there is a volt watt optimization where it is meant to squeeze maximum real power during availability and to reduce the burden on energy storage devices. DSM, so standard World Bank definition states that it is a systematic utility and government activities designed to change the amount and the timing of the consumers use of electricity for the collective benefit of the society, the utility and its consumers. So you can see here this is the demand curve. So you can see here this is a shifted consumption line and if there is a valley actually, if there is a peak and valley you can see that. So what typically we do is somehow call the demand to participate in this demand response and demand sign management program such that at any given point of time if there is a peak and valley that can be, that can be managed so that you can have a flat curve almost, like a flat load curve.

So because utility wants to see the flat load curve so that you can reduce those synchronous generation size actually which are meant to operate only at during the peak time. So you can reduce the overall operation cost as well. So and overview of automation solutions because automation will help to control in a better way. So this is how a typical SCADA based automation system looks like. So there are feeder automation, substation automation and there are control centers like regional load dispatch centers, RLDCs, state load dispatch centers, national load dispatch centers, all of

them are interconnected such that the entire grid is being monitored and controlled in a better manner.

So a typical SCADA based system with different levels of automation, the first level is process level, second level is, this is the primary level, this is the secondary level which is bay level and this is the tertiary level which is station level. In the primary level, the process level what you have is the conventional devices or the switch gears basically, the gas insulated substations or AS based switch gears, the CTs and PTs are being connected, power transformers, surge resistors and non-conventional transformers. So these devices are now communicated at the bay level with the help of IEC 61850 protocols. They are again being connected to the station level. You can see here at the bay level the functions are protection, control, monitoring, interlocking and data acquisition.

You collect the real time data and these data is being connected or processed at the station level. At the station level, the objectives are station automation, monitoring, fault elevation, event and alarm viewing and remote communication for tele-control and supervision. So there will be computers which are being placed. Once you receive the data from these ground level devices, then you will take an appropriate action whether a particular inverter being given active power or reactive power injection command or the circuit breaker operation if it has to be taken into consideration on or off or if there is a communication that need to be established with another substation for any energy market based operation. So all these principle, all these actions being taken into consideration within one substation.

So this is one substation automation features. So I will just discuss a little bit about IEC 61850 protocol. What is IEC 61850? It is a global standard for communication networks and systems for power utility automation. It specifies an expandable data model and services. It does not block future development of functions, supports free allocation of functions to devices. It provides a substation configuration language SCL and it uses Ethernet and TCP IP for communication.

So the goal of IEC 61850 standard, it is a industry preferred choice for three basic reasons. One is interoperability that means the ability for IEDs, intellectual electronic devices from one or several manufacturers to exchange information and use the information for their own functions. Because there are so many industries, Schneider, Siemens, ABB, they have their own individual manufactured IEDs. So and once you bring them together, there should be a common channel where they talk to each other and communicate to each other so that the system will be monitored and controlled in a better manner. Otherwise, if there is a communication mismatch, so the system may collapse actually.

So the IEC 61850 protocol can able to connect multiple devices manufactured by

different manufacturers. And there is a free configuration possible where the standard shall support different philosophies and allow a free allocation of functions. Example, it will work equally well for centralized or decentralized systems as well. And long term stability, the standard shall be future proof that is it must be able to follow the progress in communication technology as well as evolving system requirements. So as time proceeds, there will be new advancement in the communication technology.

So, IEC 61850 standard protocol could able to update itself with the latest communication technology so that it is capable of managing the things with even in the updated communication technology conditions. So with this, we will conclude for today's discussion which is ADMS features and its operations and management. So we will continue in the next class. Thank you very much.