Implementations of Smart Transmission Grid in Iran
(Case Study: Khorasan Regional Electricity Company)

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Abstract: *Smart transmission grid developments in Iran bring forward new requirements and challenges for the national power system. Regarding to Iranian smart transmission grid roadmap, the activities performed to implement it in Khorasan Regional Electricity Company are listed in this paper.*

Keywords: Smart transmission grid implementations; Iran national grid; Khorasan Regional Electricity Company

1. Introduction

The future developing trend of electric power networks is smart grid, which includes such features as, integration of high level of renewable energies, higher efficiency, flexibility, security, reliability, resiliency, sustainability, compatibility and cost control. Smart grid improvement is based on communication, computer and information technology with integration of infrastructures of generation, transmission and distribution power system. To deliver the benefits of the smart grid, there should be some changes in power system networks. These changes will bring different requirements and challenges. The key to getting these benefits is defining the smart grid and recognizing the challenges, opportunities and requirements to cope with.

1.1 Smart Grid Definition

"A Smart Grid is one that incorporates information and communications technology into every aspect of electricity generation, delivery and consumption in order to minimize the environmental impact, enhance markets, improve reliability and service, and reduce costs and improve efficiency" [1] and can integrate the actions of all users who are connected to it intelligently, in order to deliver economic, reliable, and secure electricity supplies [2].

For years, two-way communication technology has been used in industries. After smart grid concept, two-way communication is being used on electricity grids, from the generation units to the electricity customers and offers many benefits to both utilities and consumers [3]. In other words, smart grid means "digitalizing" the electric utility network [4].

IEEE defines a smart grid as "an automated, widely distributed energy delivery network characterized by a two-way flow of electricity and information, capable of monitoring and responding to changes in everything from power plants to customer preferences to individual appliances" [5].

1.2 Smart Transmission Grid

According to voltage level, an electric power system can be divided into distribution, subtransmission, and transmission systems. Power transmission network interconnects power plants by using overhead lines with operating voltage exceeding 230 kV to large substations generally.

The characteristics of a smart transmission grid are illustrated as below:

- High reliability and security
- Flexible controllability
- Resiliency against physical and cyber attack
- High power quality
- Advanced power electronics
- Self-healing
- Two-way communication
- New market aspects
- Aggregating generations and storage options
- Integration high levels of renewable energies
- Optimizing assets and efficient operating
- Smart sensing and measurements
- Advanced monitoring, alarming and maintenance

Smart transmission grid is achieved by integrating the existing transmission network assets and infrastructures. Reliability, sustainability, security, efficiency and quality

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of power system will be increased by using new technologies such as power electronics, advanced metering and sensors, communication and information technology, artificial intelligence and advanced computing, image and signal processing [1].

Significant activities have been carried out to develop and promote a vision for the future smart power networks [6-7]. These activities mostly emphasize the distribution grids, and future smart transmission networks are not discussed in them, so the concepts and characteristics of a smart transmission grid and Khorasan Regional Electricity Company's (KREC) roadmap towards them have been introduced in [8]. Due to IGMC's decision, (Iran Grid Management Company), KREC is the pilot of implementing smart grid in Iran.

2. Iran National Transmission Grid Current State

Ministry of Energy is responsible for energy policy in Iran and associates with 16 Regional Electricity Companies, which are in charge of all high-voltage electricity transmission and subtransmission networks. In this paper, the focus is on Khorasan Regional Electricity Company, which is the largest regional electricity company in Iran and located in north-east and east of Iran. Its area is about 1/6 of the country, and the transmission and subtransmission voltage levels are 400 kV and 132 kV respectively.

The KREC's dispatching center (North-East Dispatching Center) is one of the most modern and newest dispatching centers in Iran. The network manager software is ABB Iranian version 3. The North-East Dispatching Center main task is to guarantee the security, reliability and efficiency of operations in KREC power system; moreover, its synchronous operation with other regional electricity company and Turkmenistan behalf of the National Dispatching Center.

Overhead optical fiber cable is known as an essential element in telecommunication networks. In order to transfer data and communicate, Regional Electricity companies are expected to install OPGW cable system on high-voltage electric lines. Transmission substations become a grid via SDH fiber optics, but there are various communication media such as PLC, satellite, microwave, leased line, etc. [9]. A comparison between KREC network and Iran national grid has been shown in table I.

TABLE I. Comparison Between KREC Network and Iran National Grid in 2011

Case	voltage	Iran's grid	KREC
Total installed generation capacity (MW)		61203	5171
Length of transmission lines (C-km)	400,230[a] kV	47879	2280
	132,63 kV	65117	8470
	Fiber Optic (active)	16000	690
Fiber Optic Active Nodes		120	13
Substations capacity (MVA)	400,230 kV	109405	4388
	132,63 kV	82066	6895
Peak load (MW)		41102	3002

a. 230kV transmission line in KREC is only for Turkmenistan tie line.

3. Smart Transmission Grid: Needs and Challenges for KREC's Transmission Network

The future smart transmission network is supposed to deal with challenges including intelligence, digitalization, sustainability, flexibility, resiliency and customization. The expected characteristics and features can be attained through technologies listed below [10]:

- Measurement and smart sensing
- Alternative clean energy resources
- Power electronics and new materials
- Smart Communications
- Advanced control and computing methodologies
- Power market regulation and policies.
- Smart technologies

The application of these technologies in sub systems of smart transmission grid, including smart control centres, smart substations, and smart transmission networks has been discussed in next sections. Moreover, KREC's capabilities and requirements, assets and opportunities in a smart transmission grid have been considered.

3.1 Smart Control Centers

New functions of a Smart grid such as monitoring and measurement, analytical and computational capability, electricity market interactions and controllability of the future control centres are referred in this section.

1) Monitoring and Measurements

In existing systems, data collection is performed via SCADA systems and remote terminal units (RTUs). In future smart control centers, information and data are acquired through measurements done by phasor measurement units (PMUs) [11].

Network manager software in North-East Dispatching Center is ABB Iranian version 3 and data collection is generally through RTU560-ABB. In expected smart control center, data collection and monitoring are based on PMUs. Some PMUs have been procured by KREC, and their installation is under research and study. In the future, all transmission measurements in KREK are done via PMUs.

2) Analytical and Computational Capability

The expected contingency analysis for future control center is an online time-domain-based analysis. This analysis considers voltage stability, transient angular stability and small-signal stability, which would be provided by PMUs' measurements.

The analysis of steady-state contingencies in existing control centers is done by online tools. The analysis is performed by ranking contingencies and by using power flow each major contingency is being studied. In future, the contingency analysis is an online analysis based on time-domain and considers small-signal stability, transient angular stability and voltage stability, which would be provided by PMUs' measurements.

Contingency ranking and analysis in North-East Dispatching Center is performed by PAS (Power Application Software). After installation of PMUs in KREC transmission network, small-signal stability, transient angular stability and voltage stability will be possible due to real-time phasor data.

In North-East Dispatching Center, management and control actions are taken based on offline studies, but it is planned to perform real time management and control [9].

3) Electricity Market Interactions

In the future, Smart grid is strongly interacted with the electricity market. Advance infrastructure in smart transmission grid results in an efficient electricity market [12].

3.2 Smart Substations

The main features of smart substation are listed below:

1) Smart Sensing and Measurement

In smart substation, by applying the global positioning system (GPS), the measurement signals will be time and location based and RTU will be replaced by PMU. In addition, computational intelligence will be applied in the sensing and measurement [15]. Online monitoring of conditions of different equipments results to reduction of repair time and resilient operation. It can be achieved only by advanced sensor technologies.

2) Data Acquisition and Management

In order to decentralize applications in smart grids, a vast distributed database management is required. Furthermore, the data collected from network, including PMU units, fault recorders, relays, power quality and equipment monitors should be visualized and managed [10].

3) Monitoring and Visualization

In expected smart substations, in order to improve awareness, instant alarm warnings are sent through pagers, cell phones, and the intranet to authorized users. According to increasing amount of data about fault conditions, data processing and alarm management should be more complicated and intelligent [10].

4) Advanced Connections with Distributed Resources

The integration of renewable energy and demand response resources to power network should be provided via advance control interfaces and power electronics [10].

5) Autonomous Control

A smart substation comprises fully intelligent controllers, which are decentralized and used for remedial or predictive actions, auto-restoration or normal optimization. Moreover, in case of variation in network configuration, the settings of relays can be remotely changed in real time [16].

Characteristics and features that mentioned for smart substations have not been used in KREC substations. Therefore, more attention is needed in the concept of smart substations.

3.3 Smart Transmission Networks

New features of Smart such as high-efficiency and high-quality transmission networks, advanced power electronics and flexible controllability, self-healing, advanced transmission facility maintenance, and advanced communication system are referred in this section.

1) Efficient Transmission Networks

Major regional interconnections in smart transmission grids can be linked by high-capacity and ultrahigh-voltage transmission corridors. In this case, advanced super conductors and high-capacity AC and DC facilities are used for power transmission [10].

2) Utilization of Advanced Power Electronics

In the smart transmission grid, advanced Flexible AC Transmission Systems (FACTS), high-voltage DC (HVDC) devices, and other power electronic-based devices can improve transmission capabilities. The first HVDC line in Iran which connects KREC to central national grid is under research and development.

3) Self-Healing

In the smart transmission network, conditions of assets, including transmission lines, transformers, and circuit breakers can be monitored in real time through advanced sensing, signal communication, and processing technologies [10]. By online monitoring, problems can be detected automatically, analyzed, and responded before causing severe damages.

4) Advanced Maintenance

Overall reliability of the future smart transmission system can be improved by live-line maintenance, which reduces maintenance costs and catastrophic failures. Live-line maintenance includes cleaning and deicing conductors, cleaning and lubricating moving parts, replacing spacer or dampers, connecting or disconnecting breakers, tightening or replacing bolts, and installing measuring devices or sensors [10]. KREC has a regular preventive maintenance (PM) program but regarding to advanced transmission maintenance; PM staffs will not be sent-out to different locations without any necessity [9].

5) Integration of High Levels of Renewable Energies

Integration of distributed energy resources, especially renewable energies into the conventional power system will be fully supported in a smart grid [13]. Wind energy potential is more than 5000 MW in areas under KREC's management and wind farms up to 2000 MW will be established until 2020. Participation of renewable-energy resources in the electricity market in KREC is under research and development [9].

6) Communication Infrastructures and Interoperability

Measurement units and other local applications in smart substations are linked together via high-speed local area network (LAN) [10]. Self healing communication network can assure the reliability of monitoring and control [14]. In this case, utilities should use different communication media such as: PLC, fiber-optic, IP (Internet Protocol), microwave, etc. The main communication infrastructure in KREC is PLC; moreover, fiber-optic projects such as installing OPGW cables on transmission lines are designed and implemented on the transmission and subtransmission grids [9].

4. Roadmap to Smart Transmission Grid in KREC

The roadmap to a smart transmission grid has three milestones, which are advanced metering and monitoring, advanced power transmission network, and secure and reliable communication infrastructure. These milestones are not prerequisite for each other and are achievable simultaneously [8].

As mentioned earlier, smart control centers, smart substations and smart transmission network are the main sub systems of the smart transmission grid. Therefore, moving toward smart transmission grid can be done by integrating infrastructures of these sub systems. In this section, a roadmap for KREC's future smart transmission grid is illustrated. Based on current state of KREC's transmission network, Iranian national grid condition, and the characteristics of smart transmission grids, the vision of KREC's transmission grid development are summarized in Table II [8].

TABLE II: Roadmap for KREC's Smart Transmission Grid

Sub systems	Technology	Up to 2020	2020 to 2030
smart substations	Intelligent Electronic Device (IEDs)	✓	
	Core substation infrastructure for IT		✓
	Communication infrastructure	✓	
	PMU	✓	
smart transmission network	Transmission line sensors		✓
	FACTS and HVDC terminals		✓
	Short circuit current limiters	✓	
	Communication infrastructure	✓	
	Integration high levels of renewable energies	✓	
smart control centers	Enterprise back-office (including GIS, Outage and distribution management)	✓	

5. Implementations

According to KREC's roadmap of smart transmission grid, different tasks have been planned and implemented. Some of them are listed below:

5.1 Nashtifan Wind Farm

One of the best locations for establishing wind farms is Khaf region, located in south-east of Khorasan-e-Razavi province, which has the average wind speed of about 7.5 m/s in 80 metres height above the ground.

A contract between SUNA (Renewable Energy Organization of Iran) and a private investor was held to establish a thousand-megawatt wind farm in Nashtifan, in an area around 2000 hectares, in 2010. This contract has five phases and in the first phase, a one hundred-megawatt wind farm should be installed. According to the contract, each wind turbine is a two-megawatt turbine and should install in height of 80 metres above the ground. The first phase will be exploited at the end of September 2012 with a capital investment of more than 2000 billion Rials.

Regarding the rules in Iran, each private investor should provide the facilities of grid connections for its generation or large consumption, but as an intensive KREC is responsible to construct a 400 kV substation to connect this wind farm to the grid.

5.2 Elahieh Solar Power Plant

In the site of KREC, called Elahieh, there is a 43.6 kW solar power plant. The technology of this solar power plant is based on Photo-Voltaic panels. There are different strategies for developing and upgrading this site in near future.

5.3 Comprehensive Plan of Fiber Optic Network

As mentioned before, a secure, reliable and wideband communication is an essential requirement in smart grids; therefore, much attention should be paid to the communication infrastructures because of their important roles. The best infrastructure for communication networks is fiber optic. Now, there are around 16000 km fiber optic circuits and 120 active nodes in Iran; moreover, KREC proportions are 690 km fiber-optic circuits and 13 active nodes. There is a comprehensive plan for fiber-optic network in Iran and KREC has planned to construct 2000 km of fiber-optic circuits with more than 17 active nodes until 2016, in which, more than 95% of fiber-optics are as OPGW and less than 5% as ADSS (All-Dielectric Self-Supporting) on 20 kV lines. The current communication network is based on Stream4, whose band width is 600 Mega bits per second, but the band width of future network will be more than 2.5 Giga bits per second.

5.4 FAHAM Project

FAHAM is the abbreviation of Farasamaneh Houshmand Andazegiri va Modiriat Energy, which means Intelligent Measuring and Energy Management System. FAHAM project is related to installing the AMI (Automatic Metering Infrastructure) for 3,200,000 industrial, commercial, residential and other customers in four province of Iran, including North Khorasan, South Khorasan, Khorasa-e-Razavi and Sistan-Balouchestan. This project started in 2011 with a budget of around 6000 billion Rials and should be exploited until 2016. KREC is the supervisor of the project and responsible to control all assets and requirements.

The next step of the plan is installing 7 different RDCs (Regional Dispatching Centres) to control and monitor these different metering units.

6. Conclusion

The smart transmission grids have some advantages for both utilities and customers such as increasing flexibility in control, operation and expansion; improved resiliency and sustainability of grids; higher power quality with lower costs, and advanced services. In this paper, the roadmap for the KREC's future smart transmission grid has been surveyed and some examples for implementations of smart transmission grid on KREC, which is the largest regional electricity company in Iran, have been mentioned.

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