Chapter 8
Smart distribution system

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The main idea in smart-grid concept is the integration of active communication in the power system. Traditionally, the communication in the power system is more toward the one-way approach. All the instructions of operations are given by the utility and will be operated by the controller at the load side, either by using supervisory control and data acquisition or by other simple means of communication. However, in a smart-grid topology, the load should be able to give the information to the utility or even be able to make decisions based on the feedback provided by the end user. In this chapter, the discussion on the concept of communication integration in balancing the system frequency is discussed. The load demand will adjust the power consumption by changing their operation mode, depending on their frequency condition. The technology in telecommunications has advanced tremendously within the recent decades; we do not have to reinvent the wheel. The same technology, such as the network protocols and standards, can be implemented to the existing power system to add the smart element with the aim to make the system more efficient and robust. Furthermore, the whole world is moving toward connectivity and ubiquity; the best way forward is to embrace this change and synergize the power system components with the telecommunications components to create a smarter and efficient power control system.

8.1 Introduction—key components of the smart distribution system network

Distribution system is the last part in the power system sectors that connects the power supply to the end user. In the traditional distribution network, no other power sources are injected into the network besides the substation (only one power source). This concept of single supply makes the protection system in the distribution network simpler compared to the protection scheme in the transmission line. However, due to technological advancements, small generator units based

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on renewable energy such as photovoltaic (PV), mini-hydro, wind energy, as well as the non-renewable energy based diesel generator have been introduced. These generators have been used to supply some of the load in the distribution network directly and they are known as the distributed energy resources (DER).

There are several advantages by connecting DER in the distribution network. Since the location of DER is close to the user’s location, it allows the DER to reduce the power loss in the system. For a passive network (without DER), the total power consumption in the distribution network is solely supplied by the grid, located far away from the load demand. As a result, the power losses will also increase when the current increases. This situation worsens if the $R/X$ ratio in the distribution system is high, which indirectly causes the $I^2R$ power loss to become very high. On the contrary, with the presence of DER, some of the required power source can be supplied by the DER units. This reduces the amount of transmitted power from the grid, which indirectly causes the total amount of current to lessen. This is the reason why many researchers have applied optimization methods to obtain the optimal DER output such as by using particle swarm optimization [1,2], evolutionary programming [3] and artificial bee colony [4] to reduce power losses in the network, either for a single DER unit or for multiple DER units. In general, most of the authors have used meta-heuristic techniques or other indicators, such as voltage sensitive analysis, for conducting the DER placement analysis and subsequent optimization of the DER output. However, the placement of the DER cannot be done anywhere in the system. This is due to the fact that the DER placement should be done considering some limitations such as the point of energy resources, especially for the renewable energy. Besides that, the objective function of the optimal DER is not only limited to the power loss reduction and voltage improvement, but it can also be set to improve the stability of the system [5], lowering the cost of total generation [6], minimizing the total harmonic distortion [7], controlling the stability margin for the network [8], and many more.

The term “smart grid” is becoming more popular when researchers start to integrate advanced communication technology into the power system. In the smart grid, two-way communication between the utility side and the load side can be established. This two-way communication approach will enhance the utilities’ control over the power system compared to a single-way communication approach. However, to achieve this, the smart grid requires good data communication management and architecture. This chapter will be focusing on the use of the smart communication system to enhance the control among power utility, distributed generation (focus on renewable energy), as well as smart load devices. The proposed concept is more on the communication aspect that are required in order to control the load demand in a smart house.

There are several important components that should exist in the smart distribution system. One of the main components is the capability to communicate, from the source (utility) until the load (end user). However, traditionally, the load equipment does not have this ability (to communicate). Therefore, some modifications and enhancements on the load design need to be done. The smart-grid system will fully utilize all DER technologies such as PV, smart metering, as well as smart load. All these components will communicate to achieve the same goal, improving the power system performance.
8.2 Distributed energy resources

In the modern community, PV, electric vehicle (EV), and other energy devices in the home system are able to act as the DER in the distribution network. This external source is able not only to help in stabilizing the frequency of the system, but also to generate some money from the power supplied to the grid. For a deregulated power system, the electricity price is varied depending on the load condition. Thus, when the produced power selling price is higher than the power buying price, these energy resources can be sold to the utility. On the other hand, when their price is lower than the buying price, the DER can supply its power to its load (home) and get some support from the power system. If the house is totally disconnected from the utility due to some problems, these external resources still could supply the household with the smart appliances’ (SA) collaboration. Hence, full knowledge on DER and SA categories is required, so that a good communication between DER and SA can be established. The following section discusses the different characteristics of DER in the distribution network and their operation method.

8.2.1 PV system

The characteristics of PV as a semi-conductor material have the ability to convert solar energy to electrical energy [9,10]. However, there are several difficulties in using PV systems. One of the complications is in terms of low-energy conversion efficiency of PV cells and the efficiency keeps reducing during the operational period due to the increase in the PV temperature by 4%–17% [11,12]. In general, the power output by the PV panel can be calculated using the following formula:

\[
P_{PV} = \frac{G}{C_{PV}} \times A_{PV} \times \eta_{PV}
\]

(8.1)

where \(G\) is the solar irradiance (kW/m²), \(A_{PV}\) is the the PV array area (m²), and \(\eta_{PV}\) is the PV module efficiency.

The performance of the PV system depends on the input of irradiance from sunlight and other factors such as temperature, weather, tilt angle, shading, battery efficiency, and many more. To increase the electrical efficiency of PV cells, the solar panel must absorb the maximum amount of solar radiation. However, not 100% of the solar radiation absorbed by the PV will be converted into electricity. Some of the solar radiation is transformed into thermal energy and it will reduce the electrical efficiency of the PV cell [12].

Figure 8.1 shows the comparison of voltage and current between two PV systems that are receiving different irradiation values. The increment in the irradiation value is done by installing a light reflection system near to the PV panel. The voltage curve of solar panel with the light reflection method is slightly higher than the voltage of conventional solar panel (without light reflection). The same goes to the power in Figure 8.2. The power of light reflection solar panel is higher than the conventional panel. The increased efficiency of light reflection solar panel is 25.4% more than that of the conventional solar panel.
Higher PV power output can be obtained by reducing the temperature of the PV panel, which is due to the indirect increase in the efficiency. Figure 8.3 shows that the power generated using solar panels with a cooling system and light reflection is slightly higher than the system without a cooling system. The total energy of the cooling-light reflection method is 177.792 W, while for the light reflection without the cooling system it is 170.682 W.

From here, it can be seen that the PV power output is greatly influenced by many factors and it is very difficult to get consistent output. The use of energy storage system or battery is required to support the PV installation. However, with a good communication technology in the smart grid, the load might able to respond to the PV output and the power balancing can be done to ensure that the system frequency remains constant.
8.2.2 Wind system

The selection of a renewable energy farming approach depends on the availability and the potential of the location. For example, Malaysia have higher solar irradiation reading throughout the year, on the other hand, the average wind speed in Malaysia is very low as compared to other countries. Figure 8.4 shows a one-year wind speed profile in Malaysia, where a monthly average value is in the range of 1.98–3.28 m s\(^{-1}\) \cite{13}. Thus, similar to PV power, the power output from wind turbine (WT) generation also fluctuates depending on the average wind speed and can be calculated using the following equation:

\[
P_{WTG} = \begin{cases} 
0, & V < V_{ci} \\
 a \times V^3 - b \times P_r, & V_{ci} \leq V \leq V_r \\
 P_r, & V_r \leq V \leq V_{co} \\
0, & V > V_{co}
\end{cases}
\]  

(8.2)

where \(P_r\) is the wind turbine’s rated power, \(V_{ci}\) is the cut-in wind speed, \(V_r\) is the rated wind speed, and \(V_{co}\) is the cut-out wind speed.

8.2.3 Electrical vehicle

In this twenty-first century, environmental issues have become one of the most important concerns for environmental researchers. In addition, the fluctuation on the world fuel price has put some pressure on the gasoline vehicle (GV) users. For this reason, the EV can become an interesting option due to the non-dependency of the
vehicle to the fuel price. Not only that, the usage of EV can also reduce vehicle emissions, improve the air quality [14–16], as well as help in controlling the fuel price [17–19]. Therefore, most of the giant vehicle companies such as Ford, BMW, Toyota, Honda, and Hyundai have started to do the research in improving the EV performance. As a result, unlike in the early stages of the EV (in 1912), the advancement on DC motors and battery technologies has made the EV performance nearly similar to the GV. Table 8.1 shows the performance of EV (Tesla—Model S) [20] compared to conventional GV.

                                      Table 8.1  Comparison between EV and GV performance
                                      | EV (e.g., Tesla—Model S) | GV (Sedan car) |
|----------------------------------|--------------------------|----------------|
| Environmental impact            | No emission              | Greenhouse gases|
| Travelling distance             | ±480 km (85 kW battery)  | ±500 km         |
| Maximum speed                   | 210 km/h                 | 240 km/h        |
| Average travelling cost*        | $0.107/km                | $0.019/km       |
| Refuel/recharge duration        | 9 hours 26 minute (level 2) | Minute to refuel |

* Based on the 8,000-km distance calculation:
  Cost of fuel: $3.80/gallon.
  Cost of electricity: $0.11/kWh.

However, from the distribution network’s perspective, the EV charging process can be represented as a new load in the system. With high penetration of charging process, the performance of distribution network will be affected.
On the other hand, the connection of EV in the distribution system can also act as a DER. If the power system requires additional power, the connected EV is able to sell or inject their energy into the system. Thus, several factors need to be considered in implementing the strategy, as follows:

1. The country must use the competitive electricity market in their system. Without a variation in the electricity price, customer’s charging behavior will not be influenced to help the utility in balancing the power.
2. Effective communication technology (in broadcasting the price and user selection) is required between utility and each EV customer.
3. The utility provider also needs to have intelligent computational capability to ensure that the customer and system gain advantages from the strategy.

### 8.3 Distribution grid architecture

The traditional power system requires at least three main components for the system to send power from the generator side to the consumer side. Starting from the “generation” component, the power will be sent through the “transmission” component, and dispensed via the “distribution” component. From this traditional scheme, the power is only flowing in one direction and the distribution system has the highest power loss, due to the lower $X/R$ ratio, lower voltage level, radial configuration, and others. Studies have shown that more than 70% of power losses are due to the distribution system [21]. Many approaches have been introduced to improve the distribution network performance. Capacitor bank allocation [22–24] and reconfiguration [25–27] are the examples of proposed techniques that can be used to improve the voltage profile and power loss for distribution network. Other than these two techniques, the most significant improvement can be seen from the concept of DER. By placing the DER closer to the consumer side (end load), some of the demanded loads will be supplied by the DER, while other loads will receive the power from the transmission level.

Besides that, from the protection point of view, the use of high-speed protection and automatic restoration in the existing distribution system is able to improve the efficiency of the system. Thus, before the introduction of smart-grid concept, the intelligent schemes are already existing to protect the distribution system. Many analog measurements have been changed to digital types to get a more accurate reading. The use of advanced metering infrastructure has given further improvement on measurement instrument and control utility side. Currently, the infrastructure is more focusing on one-way communication—instead of two ways.

With the integration of advanced communication between the supply and the load side, many applications of the smart distribution grid can be done such as advanced demand response scheme, accurate fault location, and service restoration. These applications will require technologies, such as sensors, telecommunication infrastructure, analysis, and optimization, to facilitate real-time decisions and to meet growing customer expectations. Thus, several components are introduced in this discussion, such as smart server (SS), the smart regional server (SRS), the
smart meter (SM), and the SA, to make communication and data management successful between the smart home system and the utility system. The network topology of the system distribution is illustrated in Figure 8.5. As the communication and data transfer in this smart system involves the SSs down to the SAs, these entities are required to have the capability to communicate and send data in both ways.

8.3.1 Smart server and smart regional server

The SS and SRS are introduced to transfer all the two-way communication between load and supply sides as well as to make some decision based on the optimization analysis. If any disturbance occurs in the distribution system, the SS will analyze and determine the appropriate action that must be taken—either from generation or from load sides. Next, the SS will communicate with SRS to determine the suitable load that can be involved in solving the problem before the final instruction is given to the SM. All the communication among SS, SRS, and SM can be done via physical network connections such as ADSL and fiber optics or Wireless technologies. Among these two technologies, the implementation based on wireless backhaul connection might able to give more advantages and reduce some installation cost as shown in Table 8.2. For instance, WiMAX can be used because its coverage is very wide (around 50 km radius) with very fast bit rates (up to 30 Mbps or more). Even at the cell edge, the speed is still around 1–4 Mbps, which is more than enough to send the data collected by the SM.
In general, the SA is categorized based on their working principles; either the appliances operate based on thermal, time, or operation mode. In order to allow the consumer to take part in the power management, the appliances must be able to communicate with the components at the power supply side. The SA is defined as appliances which are embedded with a module that would enable the home appliances (HA) itself to detect the state that it is in and schedules its task completion according to the decision by the SM.

The structure of the proposed module is as depicted in Figure 8.6, where it consists of the power metering unit, the sensing unit, the network interface card, and the controller unit. The power line connects the appliance to the module.

<table>
<thead>
<tr>
<th>Wired</th>
<th>Wireless</th>
</tr>
</thead>
<tbody>
<tr>
<td>Speed</td>
<td>High</td>
</tr>
<tr>
<td>Cost</td>
<td>High due to cable installation</td>
</tr>
<tr>
<td>Deployment</td>
<td>Slow/cumbersome</td>
</tr>
<tr>
<td>Mobility</td>
<td>Limited, only for areas covered by the wired network</td>
</tr>
<tr>
<td>Transmission medium</td>
<td>Copper wires, optical fiber, Ethernet</td>
</tr>
<tr>
<td>Network coverage</td>
<td>Limited expansion. Requires hubs, switches, and cables for network coverage extensions</td>
</tr>
<tr>
<td></td>
<td>More area is easily covered since it is wireless</td>
</tr>
</tbody>
</table>

**Figure 8.6 Conceptual module to be implemented into SAs**
(NIC), and the controller unit. The function of each component in this module can be summarized as follows:

**Power metering unit:** The entity that calculates the power consumption of the appliance and sends the data to the controlling unit.

**Sensing unit:** The entity that senses the current condition of the appliance—either “on” or “off”.

**NIC:** The entity that will modulate and send the data in the uplink direction and demodulate and transfer the information received in the downlink direction to the SA’s application.

**Controller unit:** Act as the brain for this module. It will get the data from the power metering unit and send it to the SM via the NIC. It will also sense via the sensing unit and react accordingly.

Furthermore, the SA module will receive commands from the SM via the NIC and executes the changes required by the SM. With the implementation of this module, the system will be fully automated. In addition, users can set their preferences in these modules so that when power reduction command is received, it will act according to the user preferences.

### 8.3.3 Types of load in SAs

All appliances in the house have their own operation method and it is very important to categorize all these appliances, so that the controller unit in SA will be able to give accurate instructions. In general, the appliances can be divided into three, which are time operation based (TOB), thermal operation based (ThOB), and mode operation based (MOB).

- **Time operation based**
  There are several house appliances working based on the TOB principle. Washing machine and dish washer are the examples of electrical devices that can delay or postpone their operation without giving a big impact to the consumer. Therefore, with the adoption of communication module in TOB appliance, it makes the SM able to control their operation, either by pausing or by totally stopping the operation when it is needed. With this action, the power system is able to implement indirect load shedding in the distribution load, especially when the power supply is not enough at the distribution side.

- **Thermal operation based**
  Some electrical appliances are operated based on thermal storage capacity, such as refrigerator and water heater. Thus, it can be turned on and off for certain seconds up to certain minutes without affecting their temperature. If the network losing generation sources, the controller unit in the SA module can turn off these units for a certain time until the system regenerates. However, the SM also needs to consider the behavior of equipment, such as marginal time before the load can
be turned on again. For instance, in order to lengthen the life span of the refrigerator, it cannot be turned on immediately after the turning off process.

- **Mode operation based**
  
  For the load that can function in multi-mode operating conditions, the SM can request all these SA to change their mode when it is needed. However, the operation mode changes depending on the consumer settings. Air conditioner is one of the examples of the SA unit under this category. So, the user can set the range of the operation, for instance, from 19 up to 25 °C during day time, and the SM will run the analysis to decide the suitable temperature that will be allowed. The higher the temperature setting for the air conditioner, the lesser the power consumption from the grid will be required; therefore, the adjustment of the operating mode able to give extra available power in the system.

Table 8.3 shows the example of appliance and their categories that can be used in SA to determine the suitable action when it is needed.

### 8.4 Key challenges in smart distribution system

Data credibility of information communicated between the components of the smart grid is one of the most vital parts in ensuring that the proposed scheme can work successfully. Loss in data can cause disruptions and inaccuracies on the smart grid. The data collected from the power system components (generation, distribution, etc.) can be divided into two types: critical data such as amount of power available, stability index, and frequency and non-critical data such as voltage profile and current flow. This categorization is very important in order to choose a suitable protocol to ensure the reliability of the data passed to the SS.

#### 8.4.1 Supervisory control and data acquisition

Supervisory control and data acquisition or in short SCADA is a system used for remotely monitoring and controlling a remote station with coded signals.
However, usually each remote station requires one dedicated channel; this is not very efficient since the number of channels needed increases with the number of remote stations within the system. Besides that, the system itself is isolated from the Internet; the system manager can only have access from the controller at the center. This is very inefficient and inconvenient.

Nevertheless, that is in the past. With the advent of new technologies such as wireless sensor network (WSN) and Internet of Things (IoT), it is possible to create a system that may be centralized or decentralized, a system that can be connected to the Internet and can be accessed securely anytime and anywhere. In WSN, the remote stations can be connected to the center wirelessly, while in IoT, each component in the network has the capability to connect to the Internet. In these cases, the wireless access technologies and network protocols are paramount in ensuring a secure, robust, and reliable network.

### 8.4.2 Protocol stacks of the proposed smart-grid system

In general, the internals of a network node (e.g., servers, SSs, routers, SMs, etc.) can be divided into several stacks according to their corresponding functions, which is determined using the OSI layer [28]. However, here, for simplicity, the transmission control protocol/Internet protocol (TCP/IP) stack [29] as shown in Figure 8.7 is adopted for ease of discussion. The IP stack is divided into five layers consisting of the application layer, transport layer, Internet layer, data link layer, and physical layer.

**Application layer:** This refers to the protocols that sit behind the users and utility applications based on any OS and software installed in the device. Some examples are SMTP, POP, FTP, and HTTP.

**Transport layer:** This layer determines the reliability of the data transmission by providing end-to-end data recovery. This layer also controls the data flow by integrating the data from the application layer into a single stream if there are more than one application running. Transport protocols such as TCP, user datagram protocol (UDP), and stream control transmission protocol (SCTP) resides in this layer.

**Internet layer:** The network routing and path selection as well as the logical addressing of a device is controlled on this layer. Routers, switches, and IP operate on this layer.

![Figure 8.7 Example packet structure used for (a) in-home communication and (b) out-of-home communication](image-url)
Data link layer: This layer formats the data sent from the upper layers into a format that can be sent through physical network connection as well as dealing with the error detection and correction. Some examples are the Ethernet and the Wi-Fi.

Physical layer: This is the physical part on a device that is used to connect itself to the network. This physical connection can be a copper wire, a fiber optic cable, or even an antenna to communicate wirelessly.

From these layers, the transport layer plays a major role in maintaining the reliability of the data communicated between network nodes. For example, smart HAs can create communication sessions among themselves via power line communication [30] using a modified version of the X10 protocol [31]. In this case, both critical and non-critical data can be transmitted using the same protocol as the network is small with a limited number of devices. However, this is not enough when dealing with disruption such as packet loss and high end-to-end delay in a larger network. Due to the huge amount of clients accessing and sending data to the designated server, congestion and collision which causes the packets to be dropped are bound to happen. Thus, suitable transport layer protocols which can cope with these issues are needed.

For non-critical data, the UDP is enough since it is fast and support real-time applications. Nevertheless, it does not support acknowledgments and retransmissions. Hence, for critical data, the TCP is more suitable, as it supports retransmissions with additional congestion avoidance features. Nonetheless, TCP does not support real-time applications. One alternative that has the combination of TCP and UDP features is the SCTP. Therefore, utilization of protocols such as SCTP is desirable in maintaining the reliability of the data transmitted as well as the timeliness of the data arrival.

8.4.3 Message exchange in the smart system

The transport protocols in the previous section are used as the tool to pave the road (connection) between one device with another device or the SS. However, the language used to communicate is a different thing. Usually, messages are used for machine-to-machine communication, based on the messaging protocol used. Different sets of messages were designed depending on the entities involved in the conversation. These sets can be divided into three categories:

1. Messages between SA and SM
2. Messages between SM and SRS
3. Messages between SRS and SS

In previous works, the format of the communication packet was developed for the network layer. Two types of packet structure were introduced to cater for in-home communication (SA–SM communication) and out-of-home communication (SM–SRS–SS communication). For the in-home environment, the transport layer is not needed, as two-way communications is only done between the SA and SM. The source and destination are determined by the device id (e.g., media access
8.5 Case study: frequency balance in smart-grid architecture

The principle in the smart-grid approach to balance the system frequency is similar to load shedding method—however, with the two-way communication technologies, it is possible to have full control on the load condition. The main component required by a power system to maintain a stable frequency is by balancing active power supply and demand. Without this balancing mechanism, the frequency of the system might collapse and cause system to black-out. Commonly, load balancing is automatically conducted by the load frequency controller in a generator. However, the balancing mechanism could be limited by some constraints such as stability of the generators, transmission line capacity limit, and power losses [32–35]. Another technique of load frequency control is by controlling the total load consumption in a system. In this technique, the load is not connected or disconnected such as the load shedding method but instead, the load is controlled so that its power consumption can be adjusted whenever necessary in order to maintain the frequency stability. Many researchers have started to gain interest in this technique due to the introduction of controllable load and external energy sources such as EV and renewable energy (PV panel).

8.5.1 Frequency increase and drop operation

The SS is used to sense the frequency changes that occur in the system by using the method proposed in Reference 36. After analyzing and obtaining the amount of load to be increased or reduced, the SS will refer to its database and determine the available amount of load that can be adjusted in each SRS and send the data signal to select SRSs as shown in Figure 8.8. For the frequency drop operation, the SRS
receives the command to reduce the power consumption in its own region. Thus, the SRS will identify the suitable SM from its database and forward the message to the selected SMs (houses). The selection process of SM is based on their availability of load reduction and maximum reduction on power losses. After the SM

\[ \Delta f \]

\[ \Delta P_{\text{load}} \]

Select SRS base on maximum availability of adjusting load value:

\[ \Delta P_{\text{increase}} \text{ or } \Delta P_{\text{decrease}} \]

SRS sent the task to selected SMs (Houses)

Update adjustable load amount

Divert power from PV to external storage system (battery)

Send power from PV to distribution system – ignore pricing factor

Positive frequency slope

Increase load consumption:
- Turning “on” smart appliances
- Change mode to higher mode
- Charging EV

Reduce load consumption:
- Turning “off” smart appliances
- Change mode to lower mode
- Discharging EV

Negative frequency slope

YES

Frequency at setting point?

NO
gets the signal from SRS for adjusting their power consumption, it will ask the SA to reduce their power consumption in order to improve the frequency of the system. Not only that, external energy storage system, such as EV, will also support the system by supplying generated power to the distribution system. Once SA takes action, the SA will update the latest condition to SRS through SM. The SS will also know the changes in SRS and update its own database.

The same technique and communication management among SS, SRS, and SM will be used for load increment when the frequency in the system increases. The only difference is the condition of power consumption needed to be adjusted. In this condition, the loads will be commanded to increase their power consumption.

Figure 8.9 Messaging sequence in frequency drop operation
such as charging the EV and turning “on” the appliances which have delayed their task before this. The output from PV will not be supplied to the distribution system in this condition but it will be stored either by charging the EV or external batteries.

8.5.2 Message exchange in frequency operation

An example of message exchange between the entities within the smart system is shown in Figure 8.9. The SS will first communicate with SRS which, in turn, will analyze and select the most suitable SMs that can be adjusted. The SRS must give an acknowledgment to SS after the SRS–SM connection established. If not, the SS will communicate with other SRS. Next, the SRS will send a load adjustment request to the selected SMs, either to increase or to reduce the load depending on the frequency condition. If it is a frequency drop operation, the SRS will ask SM to send a “turn off” command to the related SAs and vice versa. Again, these SAs need to send acknowledgment messages to the SM before turning off and this message will be forwarded toward the SS, so that the SS can update its database for further analysis. With this approach, the status of the system can be updated in real time, allowing the system to maintain its stability and efficiently solve any problems or failures.

8.6 Conclusion

With the inclusion of two-way communication elements within the power system, it is possible to monitor the condition of the system in real time. This is especially useful in predicting the upcoming problems or failures; consequently, effectively avoid any system failures. The system discussed in this chapter is one of the early steps toward a more proficient power system management and maintenance. Currently and in the future, the monitoring approach can be further enhanced with the addition of WSNs, which is a platform toward the IoT, where all entities within the power system can be accessed via Internet and system engineers can effectively monitor the status of the system. Furthermore, automated approaches can also be implemented creating a self-organized, self-healing power system.

References


Communication, control and security challenges for the smart grid


