Creating a stable 100 GW electric utility system powered entirely by wind, solar, batteries, and demand-side management (DSM) would require careful integration of several elements to ensure grid reliability, stability, and consistent energy supply. Here's a breakdown of how each component would contribute to the system:

1. Wind and Solar Generation

- **Wind**: Wind power is intermittent and highly variable depending on weather patterns, time of day, and location. In the system, wind would likely be deployed in regions with high and consistent wind resources (e.g., offshore wind farms, windy plains, coastal areas). Offshore wind farms, for example, tend to be more consistent because they can generate energy at night as well as during the day.
- **Solar**: Solar power generation is also intermittent, with energy produced only during daylight hours and influenced by weather. To ensure reliability, solar installations would need to be widespread across regions with high sun exposure. To address the daily variability of solar, the system would likely rely on a combination of distributed solar (e.g., residential rooftop systems) and large-scale utility solar farms.

2. Energy Storage (Batteries)

Since both wind and solar are intermittent, energy storage is key to stabilizing the grid:

- **Battery Energy Storage Systems (BESS)**: Large-scale battery storage can help smooth out fluctuations in renewable energy production. Batteries can store excess energy generated during periods of high wind or sunshine and then discharge it during periods of low generation, providing flexibility and reliability.
  - **Sizing**: For a 100 GW system, the battery storage would need to be substantial, likely in the tens of gigawatt-hours (GWh), depending on the desired duration of storage (e.g., for 4–6 hours of peak demand).
  - **Location**: Storage systems would need to be strategically located to minimize transmission losses and to provide energy where it's needed most. Large-scale battery storage could be placed near renewable generation sources or along key transmission routes to provide quick-response power.

3. Demand-Side Management (DSM)

Demand-side management involves shifting or reducing energy use during periods of high demand or low renewable energy availability.

- **Demand Response Programs**: This would involve incentivizing customers (households, businesses, industrial users) to reduce or shift their electricity usage during peak demand periods. For example, encouraging users to run heavy appliances (e.g., air conditioners, washing machines) during times when there is excess renewable generation (e.g., sunny afternoons).

- **Smart Appliances and Smart Meters**: These can allow for more precise control of energy consumption, enabling automatic adjustment of energy usage based on grid needs. DSM can reduce the need for additional backup generation and storage capacity.

4. Grid Integration & Flexibility

The key challenge in a 100 GW renewable-powered grid is balancing supply and demand. The grid must be flexible enough to handle the volatility and intermittency of renewable generation while maintaining stability.

- **Advanced Grid Management**: The grid would need to incorporate advanced forecasting systems to predict wind and solar generation, weather patterns, and load demands. These predictions allow grid operators to anticipate power shortages or surpluses and adjust operations accordingly.
- **Interconnections with Other Regions**: To smooth out regional generation imbalances, the system could rely on electricity interconnections with neighboring regions or countries. This would allow for the import or export of power based on availability, reducing the likelihood of shortfalls or surpluses in local generation.
- **Grid Stabilization Technologies**: Advanced technologies like **virtual power plants (VPPs)**, **grid-forming inverters**, and **dynamic voltage regulation** would help stabilize the grid as renewable sources are integrated. These technologies allow decentralized sources (like rooftop solar or home batteries) to work together as a unified system.

5. Transmission Infrastructure

To manage a 100 GW system, you would need a robust transmission network that can deliver power efficiently across regions.

- **High-Voltage Direct Current (HVDC) Lines**: HVDC lines are more efficient for long-distance transmission, particularly when integrating large-scale renewable generation from areas far from major demand centers. These lines can help reduce transmission losses and allow power to be moved across large distances without significant inefficiencies.
- **Grid Modernization**: The transmission infrastructure would need to be upgraded to handle more decentralized, intermittent power sources. The ability to handle variable generation at multiple points on the grid is crucial for ensuring reliable delivery.

6. Market Mechanisms

To integrate the various components of the system, efficient market mechanisms would need to be in place:

- **Energy Markets**: These would allow for the dynamic buying and selling of power based on real-time supply and demand. A well-functioning market can incentivize the use of renewable power when it is abundant (e.g., during windy days or sunny afternoons) and encourage the deployment of storage or DSM during peak periods.

- **Capacity Markets**: These can ensure that there is enough backup capacity (from storage, DSM, or flexible generation) to meet demand during periods of low renewable generation.

7. Backup or Flexible Generation

Although the goal is to rely on wind, solar, and batteries, there may still be periods when additional power is needed to fill gaps in generation. To avoid total reliance on fossil fuels, **flexible generation** (such as natural gas or bioenergy with carbon capture) could be used as a last resort or to balance long-term seasonal gaps. However, the aim would be to minimize the use of this by optimizing storage, DSM, and grid interconnections.

A Scenario for Operation:

Imagine it's a cloudy day with low wind speeds:

- **Batteries** would discharge energy stored from previous high-generation periods (sunny days or windy nights).
- **Demand-Side Management** would encourage consumers to reduce non-essential electricity usage (e.g., delay charging electric vehicles, turn off non-critical appliances).
- **Grid Interconnections** could import power from neighboring regions where renewable generation is higher (e.g., areas with sunny weather or strong winds).
- If the storage and DSM options are exhausted, there may be a brief need for **backup generation** from gas plants, though these should be minimized as much as possible.

Conversely, on a windy day with abundant sunlight:

- The system would generate **excess electricity**, which would be stored in batteries for later use or exported to neighboring grids.
- The system could potentially **reduce electricity prices** during such times to incentivize increased demand, such as charging electric vehicles or running industrial processes that can shift their energy usage.

Conclusion:

A 100 GW electric utility powered entirely by wind, solar, batteries, and demand-side management is technically feasible, but would require advanced technologies, a well-integrated grid, substantial energy storage capacity, and a flexible, responsive approach to grid management. It would also involve close coordination between renewable energy generation, storage systems, demand-side management, and the use of regional interconnections to ensure stable, reliable power at all times.