Statistical Study of Microgrid Based on Object Oriented Usability Indices

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Abstract- Object-Oriented Usability Indices (OOUI) quantifies the achievements of multi-objective demand side management (DSM) in a power network, which is adopted by utilities to shed some load during peak load hours. Usually, there are service contracts, and the curtailments of load are automatically done by service providers based on contract provisions. Three indices, named peak power shaving, renewable energy integration, and an overall usability Index are devised in this study to analyse DSM. The application of the proposed indices is presented through simulation performed in a grid-tied micro-grid environment for a multi-objective DSM formulation. Teaching-Learning-Based Optimization (TLBO) is the optimization tool due to its simplicity and independency of algorithm control parameters. Simulation has been done using MATLAB software. The results indicate the usefulness in determining the suitable condition regarding DSM application.

Keywords- Optimization, OOUI, DSM, TLBO, micro-grid, simulation

I. INTRODUCTION

The world gets a transit from conventional grid from to the smart grid system, renewable energy sources' incorporation has become the key issue in the present environment. In accordance with the International Energy Agency prediction, power production by renewable power resources will be almost three times in between 2010 to 2035. It will contribute 31% of the globe's entire power production, in which solar, wind and hydro will provide 7.5%, 25% and 50% respectively, of the overall renewable power production by 2035. The intermittency and climate dependency of renewable power resources make their interconnection more complex and difficult.

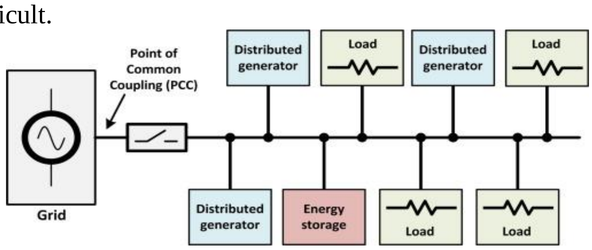

Fig.1: Micro-grid Architecture

Various energy storage devices are used to solve above mentioned problems of intermittency and weather dependency with renewable. Hence inside the smart grid environment, the development of micro grid is a great solution for integration of renewable energy sources. It has numerous advantages such as energy loss-reduction, reliability and enhancement of energy management. Micro-grid consists of different renewable power resources like wind, SPV and micro turbines. It also incorporates latest generation technologies.

To solve the above-discussed intermittency problem of renewable energy, storage devices, for example, battery energy storage system, electric vehicle technology and flywheel storage system can be used. Micro-gird provides a better solution as compared to the distributed generation sources due to their better coordination and control. It can be used as islanded mode and gird connected mode as per requirement. Hence inside micro-grid, the operation, control and coordination problem are of great importance. Further, similar to the conventional grid, micro-grid also required some cost which is related to its generation, maintenance and operation; consequently, many researches are focused on the micro-grid cost minimization problem.

Swarm intelligence dependent techniques
Firefly (FF) Algorithm
Shuffled Frog Leaping (SFL)
Particle Swarm Optimization (PSO)
Artificial Bee Colony (ABC)
Ant Colony Optimization (ACO)

Meta-heuristic optimization techniques:
Gravitational Search (GSA)
Harmony Search (HS) algorithm
Flower Pollination (FPA)
Biogeography-Based Optimization (BBO)

Fig.2: Optimisation Techniques

Meta-heuristic techniques need no gradient information. Meta-heuristics have the capability to recover from local optima due to their inherent stochastic character; consequently, it can better tackle uncertainties in objectives. It can tackle multiple objectives with only a few algorithmic changes. Normally, meta-heuristics techniques are probabilistic in nature and controlled by common parameters, e.g., population, elite population size, the number of generations

II. OPTIMISATION IN POWER INDUSTRY

The power industry is facing numerous challenges because of the fast-changing structure of the power network. The integration of small-size renewable energy sources with the conventional grid has become a significant challenge. In addition to this, the uncertainty of power availability from these renewable energy sources is also a serious concern. The search for a suitable scheme which provides a solution for technical and commercial challenges associated with the above-discussed problems is the main area of research for system operators.

Any scheme that involves alteration in operation of a complex system should be reliable to a certain level. A reliability study of a power system with DSM is important. Since a plan for load curtailment can only be prepared when load forecasting is reliable, effective optimisation techniques needs to be used. The key objectives to be kept in mind are given in figure 3. Battery storage and diesel-based energy sources are also employed with solar or wind generators to improve the reliability of the system. A DSM program for the hybrid photovoltaic system has been also proposed in the literature. The target of DSM was set to minimize the system component size and extension of battery life. This indicates that the system operation and its reliability can also be improved through DSM.

1. Load Forecasting Programs:
   - Stochastic Optimization
   - Gray Wolf Optimization (GWO)
2. Load Shifting Programs:
   - Corrective load shifting programs
3. Load Profile Prediction Methods for DSM
4. Key objectives of DSM:
   - Minimization Of Cost
   - Minimization Of Emission
   - Minimize the system component size
   - Maximize of battery life.

Fig.3: Objectives of the DSM process

The energy planning and management can be done in a certain advance time duration. This can be done as day ahead scheduling, Hour ahead scheduling, or Real-Time Scheduling. Recently, demand response-based hierarchical energy management of micro-grid was used using a scenario-based optimization scheme. In an hourly scheduling study, it was found that the payment for community aggregated electricity consumption can also be reduced through optimal hourly scheduling of electrical loads. The electrical appliances can be scheduled for optimal consumption. An informatics solution for optimal scheduling is also available where grid interacts with different appliances and utilities and coordinates the optimal scheduling of loads. The algorithm is based on the interaction between different sources and operates a demand response for energy management. The load reduction has been done based on a shifting optimization algorithm. This method successfully lowers the electricity consumption.

III. OBJECT-ORIENTED USABILITY INDICES (OOUI)

Peak load shaving and increased integration of renewable sources were identified as the main objectives of a demand-side management program. A usability index presents the fulfilment of these two objectives in any specific case study via quantified numerical factors. The outcome of any demand response program does not contain any such indices directly based on which the relative fulfilment of these objectives could be identified. In the absence of such indices, the policy decision of going with demand-side management may not produce the optimized result all the time. Therefore, OOUI are proposed in this section to indicate the relative fulfilment of the two main objectives.

In a power network, the electricity demand varies with time which is presented through the load profile. The power operator faces a challenge of balancing load and generation when peak load conditions appear. Demand-side management, when appropriately performed, reduces some load in peak hours and relieves the operator's stress. Load factor, which is the ratio of the average load on the generator over a period of time to the peak load in the same time interval, indicates the variability of the load. A low load factor indicates that the load is highly variable. A high load factor is desirable for the economic feasibility of plant. If a demand response program performs as per the requirements, it should reduce the load in peak hours and, therefore, the load factor should improve after allying DSM. A peak power shaving factor is defined as:

$$m_{pps} = LF_{DSM} / LF_{WDSM}$$

Where, LF_{DSM} is the load factor of the power network when DSM is applied and LF_{WDSM} is the load factor of the power network when it operates without demand response. If DSM successfully shaves the load in peak hours, then the load factor will improve and the peak power shaving index will be greater. For better peak power shaving operation, m_{pps} should be as high as possible.

Renewable energy generators are often small in size and unpredictable in terms of availability. Therefore, the generation support from these sources may or may not always be helpful for the power operator. A good demand response program, in terms of renewable energy integration, is one which ensures a good amount of load satisfied with renewable energy sources. A renewable energy integration index indicates the percentage utilization of electrical energy from renewable-based sources. This index is given as:-

$$m_{rei} = P_{gr} / P_{gt}$$

Where P_{gr} active power is supplied by renewable energy sources and P_{gt} is the total active power supplied.

An overall usability index which indicates the fulfilment of both the objectives of DSM is presented by OOUI. Depending upon the specific system architecture and policy-related decisions, the relative weighting of these two indices may vary. Therefore, the overall usability index also includes the individual weighting and is defined as:

$$m_{dsmuf} = w_{pps} * m_{pps} + w_{rei} * m_{rei}$$

IV. SIMULATION AND RESULTS

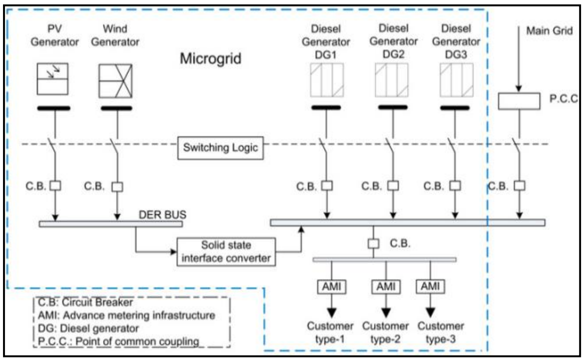

Fig.4: Microgrid Structure under study

One of the main purposes of DSM is to reduce the stress on the operator. The sudden high demand from the load in some hours of operation puts stress over the system. Therefore, the index which shows the benefit in terms of reduction of load should be an indicator. Peak power index analysis can be done under the following points:

a) *Peak power shaving index greater than one that is $m_{pps} > 1$*
b) *Peak power shaving index less than one that is $m_{pps} < 1$*
c) *Peak power shaving index equal one that is $m_{pps} = 1$*
d) *Comparative result of peak power shaving index obtained for DSM solutions*

Simulation results of the multi-objective formulation of the DSM using the TLBO method is performed in MATLAB environment. Determination of OOUI is also done.

First of all, a micro-grid multi-objective DSM formulation (F(X)) is conducted. In the next step the TLBO algorithm is adopted to solve F(X), and the optimized results are obtained. From these solutions the proposed OOUI are calculated and made available to the operator. A MATLAB-based simulation has been performed to obtain all of the simulation results. It is considered that the participation of all loads is equally shared, and each type of load has equal right to make a decision to get involved in the demand response program. The micro-grid operator the information about the interruptible energy limit of the user on per day bases and this information is used to index the end users in order of increasing interest to diminish their energy need. Additionally, the outage cost function coefficients ($K_{1,i}$ and $K_{2,i)}$ of involved users are considered to be known to the operator.

Solution of the multi-objective formulation of DSM is obtained using TLBO for five different scenarios of renewable energy availability in the micro-grid. The results indicate that the optimization target is achieved around 2000 iterations in all cases.

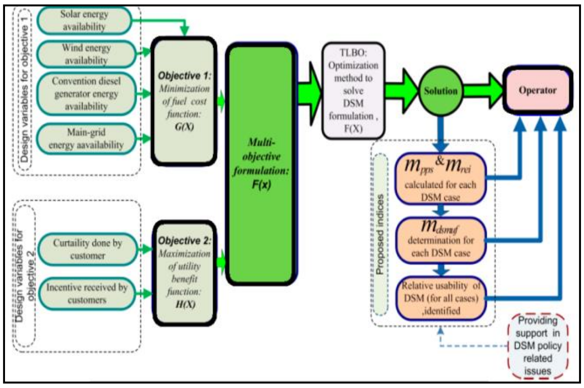

Fig:5. Indices application in a grid-tied micro-grid

As a result of the optimization new load profiles are obtained for each case.

Cases	Total Demand (kW)	Avg. Demand (kW)	Peak (kW)	Load Factor	Renewable Energy Availability (kW)	Renewable Energy Availability (%)
case 1	780.236	32.50983	39.25754	0.828117	346.24	34.62
case 2	793.9236	33.08015	41.66873	0.793884	400.45	40.04
case 3	767.8551	31.99396	39.95539	0.800742	275.03	27.50
case 4	771.3937	32.1414	40.25102	0.798524	362.76	36.27
case 5	775.5615	32.31506	39.35548	0.821107	296.01	29.60

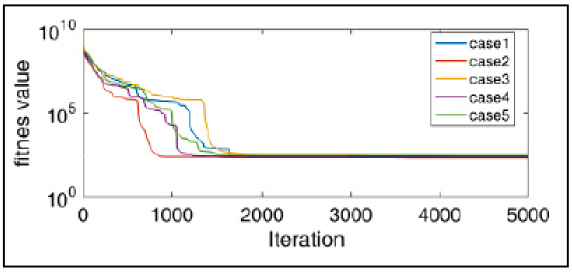

Fig.6: Test cases and Convergence curves of TLBO in the case of the *F*(*X*) objective

V. CONCLUSION

The study is to provide the OOUI, namely, peak power shaving index, renewable energy integration index, and overall usability index. OOUI allows quantifying of the technical and economic benefits from DSM. The formulated indices are helpful for the operator in identifying the relatively more suitable operating condition, and relatively more beneficial, for DSM, which can help in policy-related decisions. The economic benefit of demand response can also be quantified using the proposed index mechanism.

The overall importance of this paper is that it provides a mathematical tool for OOUI. These indices provide additional aid to the operator in identifying the conditions in which DSM provides more benefit in terms of peak power shaving and renewable energy integration. Thus, it can help the operator in policy-related decisions.

VI. REFERENCES

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