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New Technique to enhance Hybrid Renewable Energy Resources Operational Flexibility and Reliability

Tariq MASOOD[2], Jamil ABDO[1], Abdul Jabbar KHAN[3]

[1,2] Department of Engineering
101 Braddock Road, Frostburg, Maryland, 21532

[3] National Transmission & Dispatch Company, WAPDA, House Lahore Pakistan

Abstract. *In this research four integrated strategies proposed and discussed for increasing the flexibility of hydropower operations. This initiative seeks to understand, enable, and improve the contribution of hydropower, including pumped storage hydropower (PSH) to reliability, resilience, and integration in the rapidly evolving U.S. electricity system. Hydropower's flexibility is central to enhancing all these contributions. Four KFA (key focus areas) listed below to maintain and reliable operations. These KFAs will develop a suite of advancements that improve hydropower flexibility at multiple scales: improved components within the plant, improved hybridized capabilities at the plant interconnection, and improved operations across the fleet.[1],[2],[3]*

1. *HSE in Hydropower Hybrids*
2. *Reliable productivity*
3. *Technologies to Increase Flexibility*
4. *Operational Flexibility*

Key words. *Novelty, Corrective Maintenance and Preventive maintenance and Intelligent module.*

Words	Definition
DMR	Damage mechanism review in process
RBI	Risk based inspection
HSE	Health, Safety & Environment
KPI	Key Performance Indicator
FMEA	Architecture integrated Information system
PM/CM	Preventive Maintenance/ Corrective Maintenance
RTOC	Real-time operating center
FSU	Frostburg State University
MOC	Management of Change
MICE	mechanical Integrity of Critical Equipment
RCA	Root cause Analysis
FMEA	Failure mode & effects analysis
VFT	variable-frequency transformers

1. Introduction

The electric power system is vast and complex, integrating conventional and unconventional distributed power generation resources. These power resources are characterized by sharing varying renewable sources, which consist of *Geothermal, Fuel Cells, Green Hydrogen, Nuclear Energy, Wind Power, Biofuels and Biomass, Hydroelectric Power, Solar Thermal Energy Systems, Photovoltaic Systems, Greenhouse Gas Accounting.* At the same time, sharing electricity is accomplished through increased renewable sources. Industrial advances and environmental concerns make the interconnection of renewable energy sources a tendency toward the distribution generation network to enhance operational flexibility: [4],[5],[6]

(a) Hydropower mode of delivery. Physics of hydrology. Power, head, flow rate. Turbine hydrodynamics
(b) reduce environmental impact, minimize investment in power plant construction, equipment, and cost,
(c) increasing energy stable efficiency
(d) ride-through capability provided by energy storage and
(e) alleviate consequences of sudden grid outages; microgrids are becoming popular.

The US power network comprises Eastern Interconnections, Western Interconnections, Texas Interconnection, Quebec Interconnection, and Alaska Interconnection.[7] These Interconnections are tied to each other via high-voltage direct current power transmission lines (DC ties) or variable-frequency transformers (VFT)[8]. The Eastern Interconnection is tied to the Western Interconnection with six DC ties, the Texas Interconnection with two DC ties, and the Quebec Interconnection with four DC ties and a VFT [9]. The VFT permits a controlled flow of energy while also functionally isolating the independent AC frequencies of each side[10],[11]. After successfully implementing Hybrid Hydro Electric power operations, the legacy power system may move to evolving power system operations and control.[12],[13],[14]

(a) Power quality and stability
(b) Frequency regulation
(c) Spinning reserve
(d) Load following and ramping
(e) Forecasting and system protection

2. Research Proposal Scope

The distribution generators vary based on load demand. Microgrid structures are designed to meet customer requirements by incorporating renewable energy resources[15],[16]. The microgrid structure consists of five major components to make power system operations more reliable and flexible [17],[18],[19].

- micro sources or distributed generators,
- flexible loads,
- distributed energy storage devices,
- Control systems and the point of standard coupling components, connected to a low-voltage distribution network, can operate in a controlled, coordinated manner in both the connected to the utility grid or landed states.

Different approaches exist to the operation of microgrids. Other types of renewable energy resources are involved as the power generators in a microgrid [20],[21],[22]. The components within microgrids form a wide variety. The elements of the microgrid are shown in Fig.1. A simplified microgrid system is equipped with (a) controllable generation like diesel generators and load banks, not controllable generators (limited) like the photovoltaic cell and wind turbine, and (c) distributed energy storage like batteries and super-capacitors as schemed in Figure 2. Storage units can balance reserves within the short-term to long-term application range [23],[24],[25]. The flexible microgrid is connected to the upstream network, which can receive the whole or partial energy from the primary grid. When connected to a grid, it can both receive or inject power into the primary grid, indicating that it can improve the grid efficiency and resolve energy crises to a certain degree. Some examples of sustainable energy systems used in the research and articles for energy management operation of microgrid. [26],[27],[28], [29]

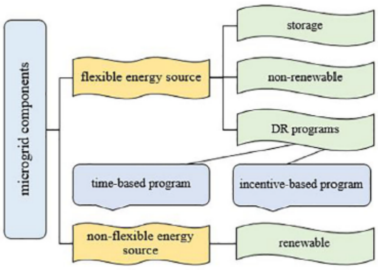

Fig.1 flexible microgrid components

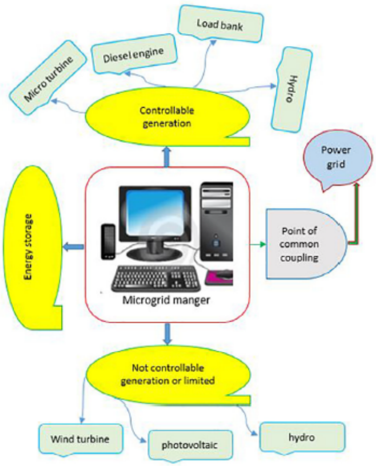

Fig.2 flexible integrated grid components

3. Hybrid operations

In conventional distributed power generation networks, e.g., thermal power generation, the generator control system frequency is controlled at a set value by adjusting power output [30],[31],[32]. However, inverter-connected Renewable Energy sources do not contribute to frequency control due to their fluctuating characteristics. The large scale of fluctuating RE power would cause fluctuation of system frequency [33],[34]. The frequency fluctuation could cause tripping renewable inverters, large-scale generation loss, instantaneous frequency drops, and more renewable inverters. Hybrid Hydropower systems provide high-level operational reliability and flexibility by integrating with other RE resources.[35],[36]

1. New Energy technologies and services
2. Increasing penetration of variable renewable on the grid
3. New communication and controls
4. Integrating distributed energy storage
5. Electrification of transportation

Valued can be derived from the renewable sources as witnessed in years 2003-2015 based on net-load how much solar system compensated as shown in Fig.3[37]. The grid services and flexibility also demonstrate solar mitigate value erosion through plant operational control as indicated in Fig.4. in the last instances Fig.5 indicates the increased operational flexibility, storage of power (Hours, not days) shifts the timing of solar and makes it dispatchable.[38],[39]

4. Power Network Performance

In this model the Smart devices are employed on the two-bus system and its computation. This describes the set of tailored equations which are an essential to develop the model and synthesize in two bus system and simulate to achieve desired results on the electrical power system[40].

$$R_1, X_1 = L_1 \omega R_s \ldots\ldots\ldots\ldots\ldots(1)$$

$$X_s = L_s \omega \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(2)$$

Equation (1) and (2) values are computed by considering short circuit power references. There are two critical parameters must be considered (1) XR=X/R ratio (2) power system short-circuit to witness required results. Further assessment can be performed as given below. Wherein the X=Lω and the operative parameters of the electrical power transmission-network are computed rigorously to integrate, by using the equations (3) and (4) as given below[41].

$$R = \frac{V_n^2}{S_{sc}\sqrt{1+XR^2}} \ldots\ldots\ldots\ldots\ldots\ldots(3)$$

$$L\omega = XR \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(4)$$

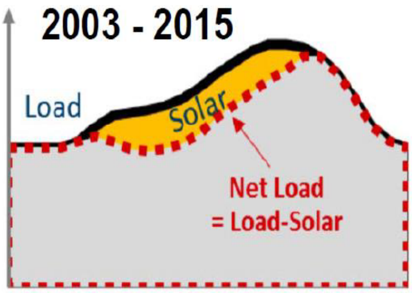

Fig.3 Value derived

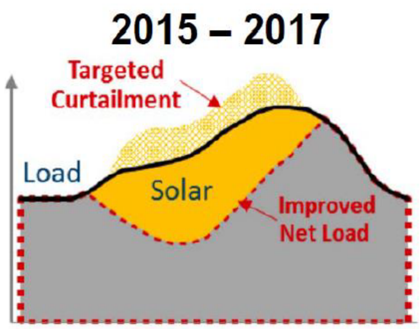

Fig.4 Grid Services

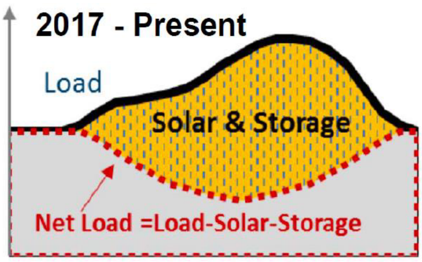

Fig.5 Increase Flexibility

5. Operational flexibility Results/Discussion

The Hybrid plant operations designed and developed numerous initiatives to implement operational flexible initiatives in the line of production best practices. Based on that, these constituted four strategy groups: ***Fig.6 shows the Operations reliability& its integral components, Fig.7 shows the Process Equipment Reliability Model, Fig.8 shows the RIM- Record Information management system, and Fig.9 shows the Electrical and Instrument control model.*** These Models are integrated to implement in line with the operational strategy to enhance equipment operational flexibility and integrity to address the challenges to maximize equipment uptime to achieve zero trip incidents. [41]

1) Inspection plan, Rules, and responsibilities to determine operational behavior of the facilities: pumped storage, spillways, crossflow, and gates
2) PMs completion >90% target
3) enhance operations and maintenance staff skills, which is cost-effective.
4) strictly following Standard Maintenance procedure (SMP) for jobs in the field
5) Inspection, Testing, and Preventive Maintenance (ITPM)
6) Equipment Deficiency Management
7) Quality Assurance / Quality Control
8) Written Procedures
9) Training
10) Continuous improvement
11) Audits & Metrics Review
12) DMR (Damage management review) and its prevention mechanism, a comparative analysis recommended, and how we are executing DMR/ prevention to be completed by the **corrosion and inspection team**).
13) MICE completion to be 100% **(mechanical Integrity of Critical Equipment). The reliability team** needs to check the status of the MICE, how we have set MICE criteria, and the completion ratio of PM and CM as planned in percentage.
14) A thickness monitoring mechanism has also been implemented at different locations of the pipeline and high pressure; based on that, we are determining potential leakage or slippage.
15) Rotating equipment to implement FMEA through Meridium management software.
16) Risk-based inspection (RBI) DMR also complement each other
17) Based on the inspection, we have to implement recommendations to improve the system; otherwise, it will stay in the gray area.
18) Develop Inspection Testing Plans
19) MI critical equipment

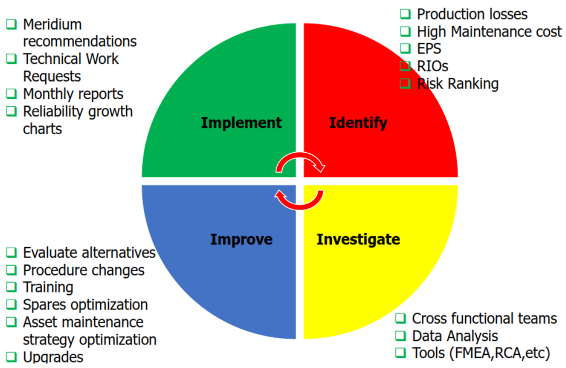

Fig.6 Operational Reliability Model

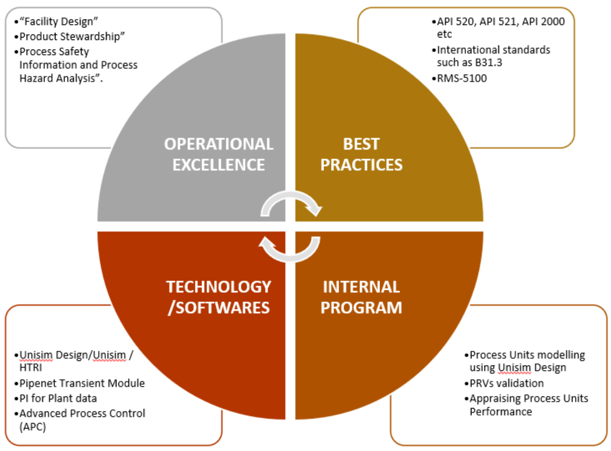

Fig.7 Process Equipment Flexibility Model

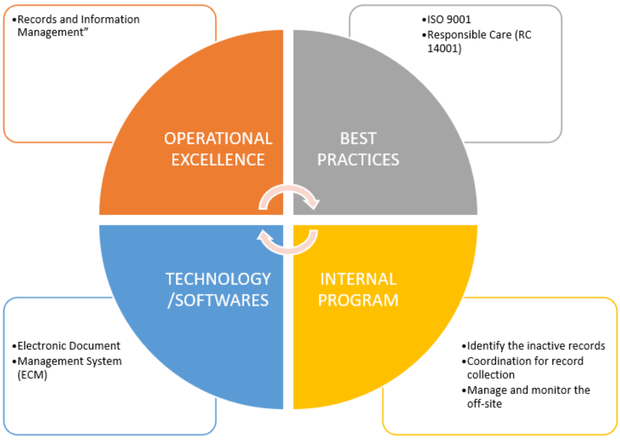

Fig.8 Process Flexibility RIM Model

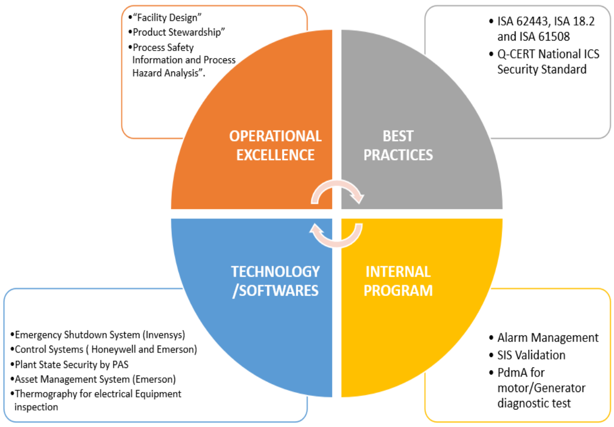

Fig.9 Operational flexibility control model

6. Conclusion

In this research, we have identified and determined to manage asset reliability risks that adversely affect plant or business operations to improve hydride operational flexibility by integrating different conventional and renewable energy resources. Effectively, the Bad Actors-Items with failures (Reactive) RIOs (reliability improvement opportunities)-Items without failures (Proactive). Cross-functional teams comprise production, maintenance, technical, and process teams.

1) *Hydropower Hybrids operations*
2) *Technologies to Increase Flexibility*
3) *Operational Flexibility*

Four strategies have been thoroughly discussed for increasing the flexibility of hydropower plant operations.

In this novelty, I am developing new operational strategies for Hybrid's different plants, solar, wind, and fuel cells. Essentially, it is to understand, enable, and improve the contribution of hydropower, including pumped storage hydropower (PSH), to reliability, resilience, and integration in the rapidly evolving U.S. electricity system. After successful implementation, these defined strategies witnessed Improved components within the plant, improved hybridized capabilities at the plant interconnection, and improved operations across the fleet.

These are critical aspects and considerations that we intend to explore in this research:

- **Hydro-resource power production**. Hydropower mode of delivery. Physics of hydrology. Power, head, flow rate. Turbine hydrodynamics; Francis, Kaplan, Pelton, Turgo, crossflow. System components: generators, governors, penstocks, spillways, valves, gates, and trash racks. Large-scale and micro-hydroelectric systems. Pumped storage. Economic and environmental considerations.
- **Hybrid Renewable Systems**: Investigate the benefits of creating a hybrid renewable energy system that combines solar and wind technologies. This can enhance the overall efficiency and reliability of the system, especially in locations with variable weather conditions.

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