Business Requirements Specification

Phase Shifter Modeling

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1. Introduction

1.1 Purpose

The purpose of this document is to capture and record a description of what the Users and Business Stakeholders of the Phase Shifter Modeling project wish to obtain by providing high-level business requirements. This document establishes the basis for the agreement between the initiators and implementers of the project. The information in this document serves as input to determining the scope of projects and to all Business Process Modeling and System Requirements Specifications efforts.

2. Intellectual Property Ownership

2.1 Checklist

The California ISO assumes the ownership of Intellectual property for this project is:

- Design of optimization model Phase Shifter (PST);
- Related Business Practice Manual;
- Software codes to implement the PST design.

3. Details of Business Need/Problem

3.1 Description

CAISO has approved installation of Imperial Valley two parallel Phase Shifters (Phase-shifting transformer (PST)) and proposed operating strategy as following:

Phase Shifter Tap control:

- Tap position for both PST1 and PST2 should be set by CAISO market while also meeting all reliability requirements. The Tap position should be the same for PST1 and PST2 to avoid any circulating VAR.
- CAISO will send Tap Positions value to PST and PST operator will move tap to follow the desired Tap value.
- PST operator will have the actual physical Tap Control system that follow the CAISO instruction

- PST operator will have the actual physical Tap Control system such that Tap Control can be manually controlled by its transmission operator in case of loss of automation or in case of emergency exceptional dispatch instruction.

3.2 Controllable Devices Modeling

The CAISO controlled grid includes controllable transmission devices that enable the CAISO as the balancing authority area and transmission operator to monitor and adjust the power flow on the CAISO controlled grid (An example of these devices include but not limited to ISO controlled HVDC, Phase Shifting Transformer, and any other controllable devices). Controllable transmission devices are designed to ensure the reliable and secure operation of the grid is maintained. Controllable transmission devices help control the power flow through transmission lines. The CAISO market systems optimizes the controllable transmission devices as part of its security constrained economic dispatch and security constrained unit commitment. The CAISO market systems will calculate and issue the optimal position for the controllable device to the transmission owner. Pursuant to operating procedures, the transmission owner modifies the controllable device pursuant to the CAISO market instruction.

The CAISO will not enforce the optimization of the controllable device in any of the CAISO Markets if the CAISO has determined that: (1) there are modeling inaccuracies, including inaccuracies in available data; or (2) doing so could result in adverse reliability impacts

4. Business Process Impacts

4.1 High Level Description of Business Process

Manage Markets & Grid

4.2 Definition and Acronym

Acronym	Term
CAISO	California Independent System Operator
CIM	Common Information Model
CRR	Congestion Revenue Rights
DAM	Day-Ahead Market
EDR	Enterprise Data Repository
EMS	Energy Management System

FMM	Fifteen Minute Market
HVDC	High Voltage Direct Current
ICCP	Inter-Control Center Communication Protocol
IFM	Integrated Forward Market
MF	Master File
NA	Network Application
PST	Phase Shifter, or Phase-Shifting Transformer
RTCD	Real-Time Contingency Dispatch
RTD	Real-Time Dispatch
RTM	Real-Time Market
RTPD	Real-Time Pre-Dispatch
RTUC	Real-Time Unit Commitment
SCUC	Security Constrained Unit Commitment
SFT	Simultaneous Feasibility Test
STUC	Short-Term Unit Commitment
WebOMS	Web-based Outage Management System

4.3 Justification

Installed new Phase Shifter Transformer provides technology feasibility for the ISO to control the Phase Shifter and manage the power flow directly in the market. Include PST tap position in the market optimization will benefit grid reliability and market efficiency.

5. Business Requirements

The sections below describe the Business Processes and the associated Business Requirements involved in the project. These business requirements directly relate to the high level scope items determined for the project.

Impacted Systems:

Reference Data existing in Full Network Model (FNM):

- Device ID (RDFID)
- Device operator (IOU)
- Step Size (radians/step) $psss_i$
- Neutral Tap position
- Phase shifter tap maximum number (pstpmx)
- Phase shifter tap minimum number (pstpmn)

No change for PST in Full Network Model (FNM)

Master File:
- Device ID (Res id map to RDFID)
- Device operator (IOU/TO)
- Device BAA ID
- Device Type
- Phase shifter tap maximum number (pstpmx) (for market use, can be different from FNM, but must within the range of FNM defined maximum number).
- Phase shifter tap minimum number (pstpmn) (for market use, can be different from FNM)
- Phase shifter tap position base case ramp rate limits: These values limit the tap position change from one time interval to the next for the base case tap positions (steps/X-minute, for 5 minutes, 15 minutes and 60 minutes)
- Penalty cost for a step movement ($/step)
- Define parallel PST sets

EMS
- EMS shall receive telemetry of the PST for tap position in CAISO and EIM BAAs

- EMS shall receive RTD 5-minute market results of optimized PST tap position for binding interval

- EMS shall send the market optimized PST tap position to PST device operator through EMS ICCP, for binding interval at the binding interval time stamp

DAM/RTM

- System shall provide configuration option for PST optimization for each market DAM/RTPD/RTD/RTCD

- System shall receive the penalty cost for each PST from Master File. Only the PST defined in MF are included in market optimization.

- In schedule run, include penalty cost associated with tap upward and downward movements in objective function for the each PST that are subject to optimization
- PST tap position initial value:

- o In DAM optimize PST, system shall use prior DAM hour 24 phase shifter position of Phase shifter (PST) as initial tap position for the first hour of the day, consequence hour will use prior hour tap position as start point, optimize the tap position continuously.
  - o In RTPD optimize PST, system shall use the latest solved tap position, include advisory interval solution, from RTD or RTPD or DAM, as initial tap position.
  - o In RTD optimize PST, use the state estimator solved phase shifter tap position as initial tap position in optimization.
  - o In RTD, if the phase shifter optimization is not enabled, then the phase shifter tap position will be locked to its SE solved tap value for the binding time interval and RTPD solved tap values for future time intervals.
- Set Tap position as Integer Control Variable
- Set PST constraints
  - o Include shift factor and PST tap position movement from initial position impact on transmission flow constraint
  - o Enforce (max/min) limits on tap position
  - o Enforce the absolute ramp constraint for tap position movement from previous interval
  - o Enforce constraint for Phase shifter designated as parallel PST must be optimized at same tap position
    - ▪ The parallel constraint is enforced only if both PST not in outage
    - ▪ If one or both PST are in outage, the parallel constraint is not enforced
  - o Enforce PST flow limit same as regular transformer for base cases and contingency cases
- Keep different phase shifter models for optimization, regulating or passive.
- Allow operator to input Tap positions, and PST will not be optimized.
- System shall publish Tap position for RTD, RTCD, and DAM, RTPD
- Schedule run shall include penalty cost for the tap position movement and price run shall be with fixed tap position from schedule run and not include penalty cost for the tap position movement
- PST tap movement constraint will not affect LMP calculation.

NO settlement *for* Tap position of phase shifter

CRR: Use predefined monthly fixed angle value for PST in CRR

5.1 Business Process: < Manage Entity and Resource Maintenance Updates (Master File) and Full Network Model (FNM)>
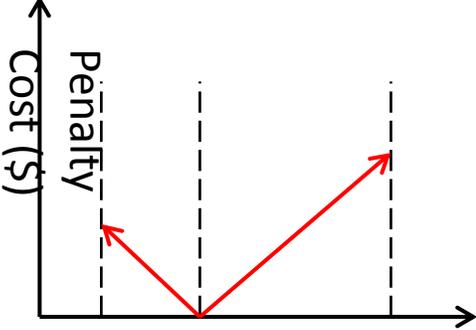
5.1.1 Business Requirements

ID#	Business Feature	Requirement Type	Potential Application(s) Impacted
PST_BRQ010	**System shall define Phase Shifter Transformer (PST) as new class of equipment with equipment characters and limits:** For each PST device, define: • Device ID • Device operator (IOU/TO) • BAAID • Device Type (For MF use to identify the device) • Phase shifter tap maximum number (pstpmx), validate the value is within the maximum value defined in FNM • Phase shifter tap minimum number (pstpmn), validate the value is within the minimum value defined in FNM • Phase shifter tap position base case ramp rate limits. (These values limit the tap position change from one time interval to the next for the base case tap positions.) ($pstpmv_i$) for 5 minutes, 15 minute and 60 minute(steps/5minute, steps/15minutes, steps/60minutes) • Penalty cost for a step movement ($/step) (PST_BRQ030) a value $/per step from the initial position Transfer script for new phase shifter Pstpmx/ pstpmn allow PST operator to provide a preferred market operation tap range.	core	Master File Transfer Script

ID#	Business Feature	Requirement Type	Potential Application(s) Impacted
PST_BRQ015	**Define parallel PST devices:** Define the set for the PST devices that are parallel, and must move at same direction and tap position. MF shall ensure the parallel PST has the same min, max, neutral taps and step size Maximum 2 PST in the set. Define which phase-shifter is the master and which one is the slave Pass the parallel PST set to the market.	core	Master File Transfer Script

ID#	Business Feature	Requirement Type	Potential Application(s) Impacted
PST_BRQ030	**System shall define PST Penalty cost for each PST:** - Define Penalty cost for each PST in $ for a step movement ($/step) Note: Figure above provides the penalty cost associated with moving phase shifter taps from its initial position The vertex point of the V curve for the first time interval will come from the initial condition. The vertex point for the second time interval and onward will correspond to the solved tap position of the previous time interval. Transfer script for PST Penalty cost	core	Master File Transfer Script

ID#	Business Feature	Requirement Type	Potential Application(s) Impacted
PST_BRQ040	**Default Tap position for the participating PST in Full Network Model (FNM)** FNM includes phase shifter • Device ID (RDFID) • Substation • default Tap position, • Step Size (radians/step) psss$_i$ • neutral tap • max/min tap for the PST The CIM data contains the default tap position, the default regulation status (fixed tap position or fixed MW flow), and the default target MW flow value used when the phase-shifter is defined as regulating the MW flow (Existing)	Core Existing functionality	FNM

5.2 Business Process: <Manage Energy Management System (EMS) and outage system (WebOMS) >

5.2.1 Business Requirements

ID#	Business Feature	Requirement Type	Potential Application(s) Impacted
PST_BRQ110	**EMS shall receive telemetry for the PST tap position of PST located in CAISO and EIM BAAs:** • Receive Telemetry for phase shifter actual tap position of the PST located in CAISO • Receive Telemetry for phase shifter actual tap position from the PST located in EIM BAA	Core	EMS, integration
PST_BRQ130	**EMS and Market shall receive PST outage from Outage system** • Outage system shall publish the PST device ID as transmission outage through breaker/switch status, PST outage is in/out status, not allow de-rate • EMS system shall receive the PST device ID as transmission outage through breaker/switch status • Market system Network Application shall receive the PST device ID as transmission outage through breaker/switch status	Core	WebOMS, integration, EMS DAM, RTM NA

ID#	Business Feature	Requirement Type	Potential Application(s) Impacted
PST_BRQ150	**EMS shall send 5-minute intervals market result tap position to PST device operator through ICCP:** • Send the RTD 5-minute binding interval tap position to the PST operator through EMS ICCP at the time of binding time stamp • EMS shall receive the market RTD PST tap position solution once market publish RTD result, and at binding time stamp to send to PST operator	Core	EMS, ICCP

5.3 Business Process: < Manage Day Ahead Market and Real Time Market >

5.3.1 Business Requirements

ID#	Business Feature	Requirement Type	Potential Application(s) Impacted
PST_BRQ220	**System shall provide configuration option for PST optimization in DAM/RTM:** • Provide configuration option to turn on/off phase shifter optimization at each application (DAM/ RTPD/RTD/RTCD), • If PST optimization flag is turned off in DAM and/or RTPD, UC will initial PST tap position for the whole market horizon and pass them to NA, but still allow operator override through the UI for any interval	Core	DAM, RTPD, RTD, RTCD
PST_BRQ230	**System shall receive the penalty cost for each PST from Master File:**	Core	Master File, Transfer script

	• Receive the penalty cost for each phase shifter when the PST optimization flag is turned on • The PST devices modeled in MF shall participate optimization when the PST optimization flag is turned on.		DAM, RTPD, RTD, RTCD
PST_BRQ240	**Objective Function** **In schedule run, include penalty cost associated with tap movement (upward and downward separately) in objective function for the each PST that are subject to optimization**	Core	DAM, RTPD, RTD, RTCD
PST_BRQ250	**Initial PST tap position in DAM:** **System shall use the prior day last hour position for DAM as the initial tap position of first hour of each day,** In DAM optimize PST, initial tap position • System shall use the prior DAM, hour 24 phase shifter position of Phase shifter (PST) at the first hour of the day, similar as generator initial condition • Subsequent hour will use prior hour tap position as start point, optimize the tap position continuously • "neutral position" will be used for the first initial tap position of a new PST	Core	FNM, DAM,
PST_BRQ260	**Initial PST tap Position in RTPD** **System shall use the latest solved tap position from RTD or RTPD or DAM as initial tap position for the first time interval** • In RTPD, the latest solved phase shifter tap positions are used as the initial tap position to UC and tap positions are optimized in the subsequent iterations, similar as generator initial condition.	Core	RTPD,

PST_BRQ270	**Initial PST Tap Position in RTD and RTCD** **In RTD and RTCD, use the state estimator solved phase shifter tap position** • Market shall receive SE solution for PST Tap positions from EMS • If the phase shifter optimization in RTD is enabled, the NA update provides the state estimator solved phase shifter tap position to UC and tap positions are optimized in the UC execution. • If the phase shifter optimization is not enabled, then the phase shifter tap position will be locked to its SE solved tap value for the binding time interval and RTPD result of tap values for future time intervals, • In the case of a forced event run, the NA update provides the state estimator solved phase shifter tap position to UC and tap positions are optimized in the UC-NA execution. In RTCD the tap position change will be limited based on 2 times the 5 minute tap position ramp rate.	Core	EMS, integration, RTD, RTCD
PST_BRQ271	**Allow operator to manually override the initial tap position:** • Allow the manual override for initial tap position DAM, RTPD and RTD at the beginning of the market optimization horizon. • Not allow the manual override PST tap position for other intervals in the market optimization horizon	Core	DAM, RTPD, RTD, RTCD
PST_BRQ272	**The PST market and publish rules summary for DAM, RTPD and RTD:** **Case1:**	Core	DAM, RTPD, RTD, RTCD Integration

Market	PST Optimization Flag On/Off	Initial Tap Position	Binding Interval Tap position	Advisory Interval Tap position	Publish Binding Interval Tap position	Publish Advisory Intervals Tap position
DAM	on	prior day last hour position for	Optimized	Optimized	Optimized	Optimized

		DAM				
RTPD	on	latest solved tap position	Optimized	Optimized	Optimized	Optimized
RTD	on	SE	Optimized	Optimized	Optimized	Optimized

Case2

Market	PST Optimization Flag On/Off	Initial Tap Position	Binding Interval Tap position	Advisory Interval Tap position	Publish Binding Interval Tap position	Publish Advisory Intervals Tap position
DAM	on	prior day last hour position for DAM	Optimized	Optimized	Optimized	Optimized
RTPD	on	latest solved tap position	Optimized	Optimized	Optimized	Optimized
RTD	Off	SE	SE	RTPD Optimized	RTPD Optimized	RTPD Optimized

Case 3

Market	PST Optimization Flag On/Off	Initial Tap Position	Binding Interval Tap position	Advisory Interval Tap position	Publish Binding Interval Tap position	Publish Advisory Intervals Tap position
DAM	Off	Default	Default	Default	n/a	n/a
RTPD	Off	Default	Default	Default	n/a	n/a
RTD	Off	SE	SE	SE	n/a	n/a

Case4

Market	PST Optimization Flag On/Off	Initial Tap Position	Binding Interval Tap position	Advisory Interval Tap position	Publish Binding Interval Tap position	Publish Advisory Intervals Tap position
DAM	Off	Default	Default	Default	n/a	n/a
RTPD	On	latest solved tap position	Optimized	Optimized	Optimized	Optimized
RTD	Off	SE	SE	RTPD Optimized	RTPD Optimized	RTPD Optimized

PST_BRQ280	**Set Tap position as Integer Control Variable** • Set tap position as control variable • The SCUC treats the phase shifter tap position as an integer variable. NA uses the discrete tap positions provided by SCUC.	Core	DAM, RTPD, RTD, RTCD
PST_BRQ290	**Set PST constraints:** Power flow: Include shift factor and tap position change impact on transmission flow constraint	Core	DAM, RTPD, RTD, RTCD

PST_BRQ310	**Set PST constraints:** Enforce limits: the phase shifter taps to be within the maximum and minimum number of allowed tap movements for the corresponding phase shifter.	Core	DAM, RTPD, RTD, RTCD
PST_BRQ320	**Set PST constraints:** Enforce ramp limits: the number of phase shifter tap movements between intervals is limited by the maximum allowed tap movements between time intervals for phase shifter.	Core	DAM, RTPD, RTD, RTCD
PST_BRQ330	**Set PST constraints** Ensures that the parallel phase shifters solves at the same tap position. • The parallel constraint is enforced only if both PST are in service • If one or both PST are in outage, the parallel constraint is not enforced	Core	DAM, RTPD, RTD, RTCD
PST_BRQ335	**Market shall ensure the PST maximum normal rating and contingency rating are observed same as other type of transformer**	Core	NA, DAM, RTPD, RTD,RTCD
PST_BRQ336	**System shall model PST outages** • PST could be taken out of service from any tap position. So there is no ramping constraint enforced for "shutting down" the PST • PST has to start from neutral tap position when being put back to service. So ramping constraint will be enforced for "starting up" the PST from neutral tap position	Core	WebOMS, Integration, DAM, RTPD, RTD, RTCD NA
PST_BRQ340	**Run NA power flow with Tap Position from SCUC to NA** Include tap movement impact on power and phase angle in the active power flow equation	Core	DAM, RTPD, RTD, RTCD NA
PST_BRQ380	**Keep three different kinds of Phase Shifter Modeling in NA and Market**	Core	NA, DAM, RTPD, RTD, RTCD

	Type 1: Phase Shifters that are considered for optimization. For these set of phase shifters, SCUC will provide the tap position and NA will use that tap position in calculations.		
	Type 2: Phase shifters that are not considered in the optimization, and are regulating the MW flow through them. NA will adjust the phase shifter angle by moving its tap to force the regulated MW flow. MW schedule has to be provided for such phase shifters and local control flag for phase shifter regulation has to be turned on to enforce this feature.		
	Type 3: Phase shifters as passive branches. These phase shifters are not included in the set that are considered for optimization and also not regulating MW flow through any branch.		
PST_BRQ390	**Allow operator to input Tap Position for PST Type 1 (defined in MF for optimization) for DAM and RTM effective period** • The market will use the operator inputted TAP position as PST fixed tap position. Market shall not optimize the PST. • Operator shall input the same TAP position for the parallel PST	Core	DAM, RTM, RTPD, RTD, RTCD BAAOP
PST_BRQ400	**IFM and RTM shall Publish Tap positions for the eligible device in IFM and RTPD, RTD,** • Publish each participating PST device ID tap position in IFM, RTPD and RTD, RTCD for the binding intervals and advisory intervals, in the same manner as resource results. • If RTD is not run optimization of the tap position, RTD shall still publish the PST tap position carried from RTPD for the applicable RTD interval. The three RTD interval will be the same value.	Core	DAM, RTPD, RTD, RTCD, integration
PST_BRQ410	**Price LMP shall not be impacted by Tap movement penalty cost, Price run shall not include penalty cost for tap movement** • Schedule run shall include penalty cost in objective function, and optimize the PST tap position. • Price run shall not have penalty cost in objective function, Price run shall carry fixed tap position that optimized in schedule run • LMP includes congestion cost of binding branch limit constraints for PST same as regular transformer. • PST tap movement constraint will not affect LMP calculation.	Core	DAM, RTPD, RTD, RTCD,
PST_BRQ420	PST Tap position model data shall be stored in save cases, and data repository system, apply same data retention policy for generator. Only the PST defined in MF shall be included.	Core	EDR

5.4 Business Process: <Manage Congestion Revenue Rights (CRR)>

5.4.1 Business Requirements

ID#	Business Feature	Requirement Type	Potential Application(s) Impacted
PST_BRQ442	CRR will use predefined monthly fixed angle value for PST.	Core	CRR

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