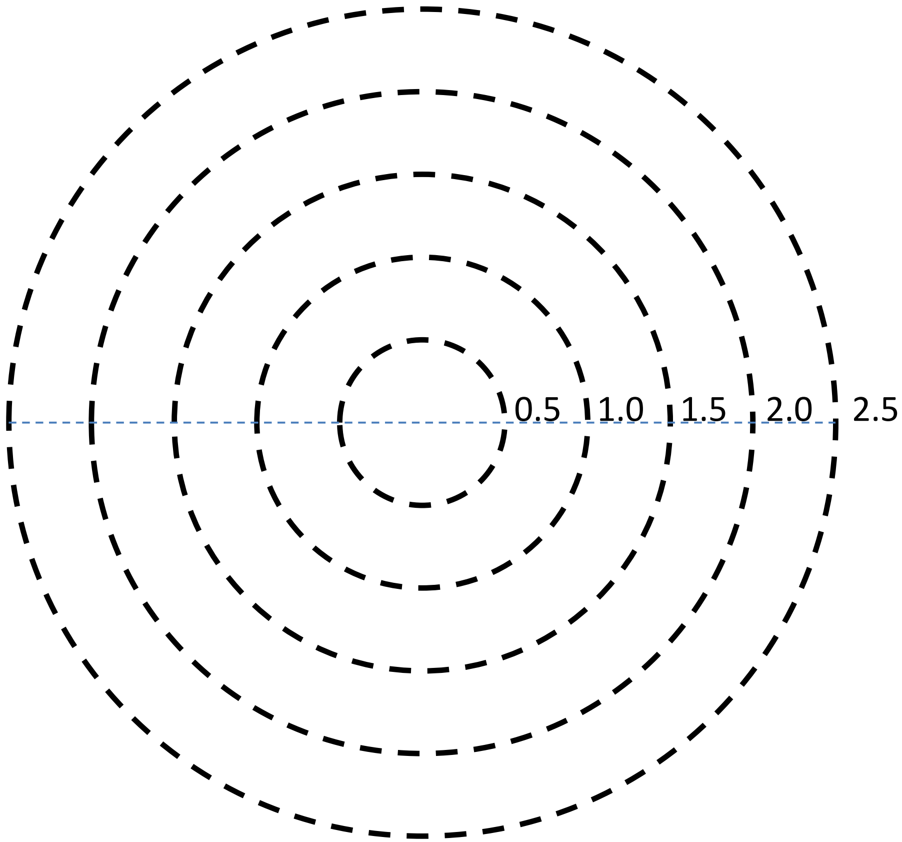
Response to steady-state set point changes in load

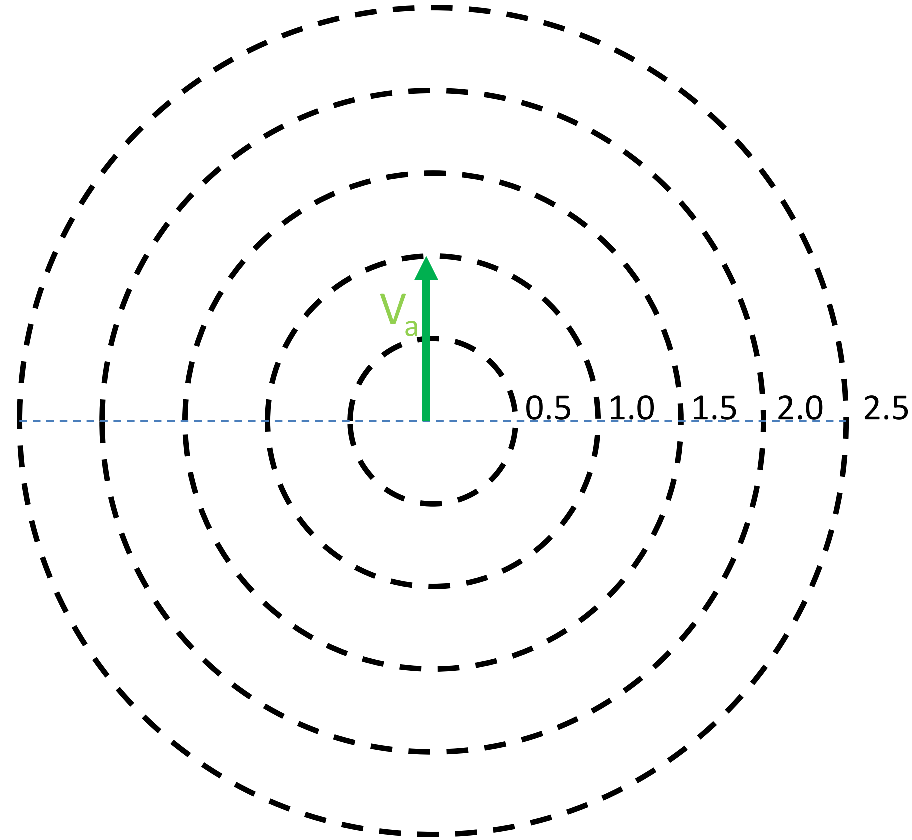
- Before considering full transient behaviour in detail, it is useful to explore the behaviour of a machine in response to changes in load set point of a generator feeding a stiff fixed voltage bus
- The steady power equation for a non-salient machine is: $P = -\frac{V_a E_a \sin \delta}{X_s}$
- At a given excitation level, an increasing electrical load on the generator will cause the load angle, δ, to increase, with a maximum value of $90°$. If the load is increased beyond this limiting value and the excitation is not changed in response (usually pre-emptive rather than reactive) then the generator will lose synchronism.
- A useful means of demonstrating the full operating envelope is a load diagram
- Consider the case of a machine with a synchronous reactance of 1.25pu (assumed to be constant)
- We will develop and then use the load diagrams in a series of steps

Construction of load diagram for 1.25per unit synchronous reactance

Establish circular contours of constant excitation



Draw on rated per unit voltage

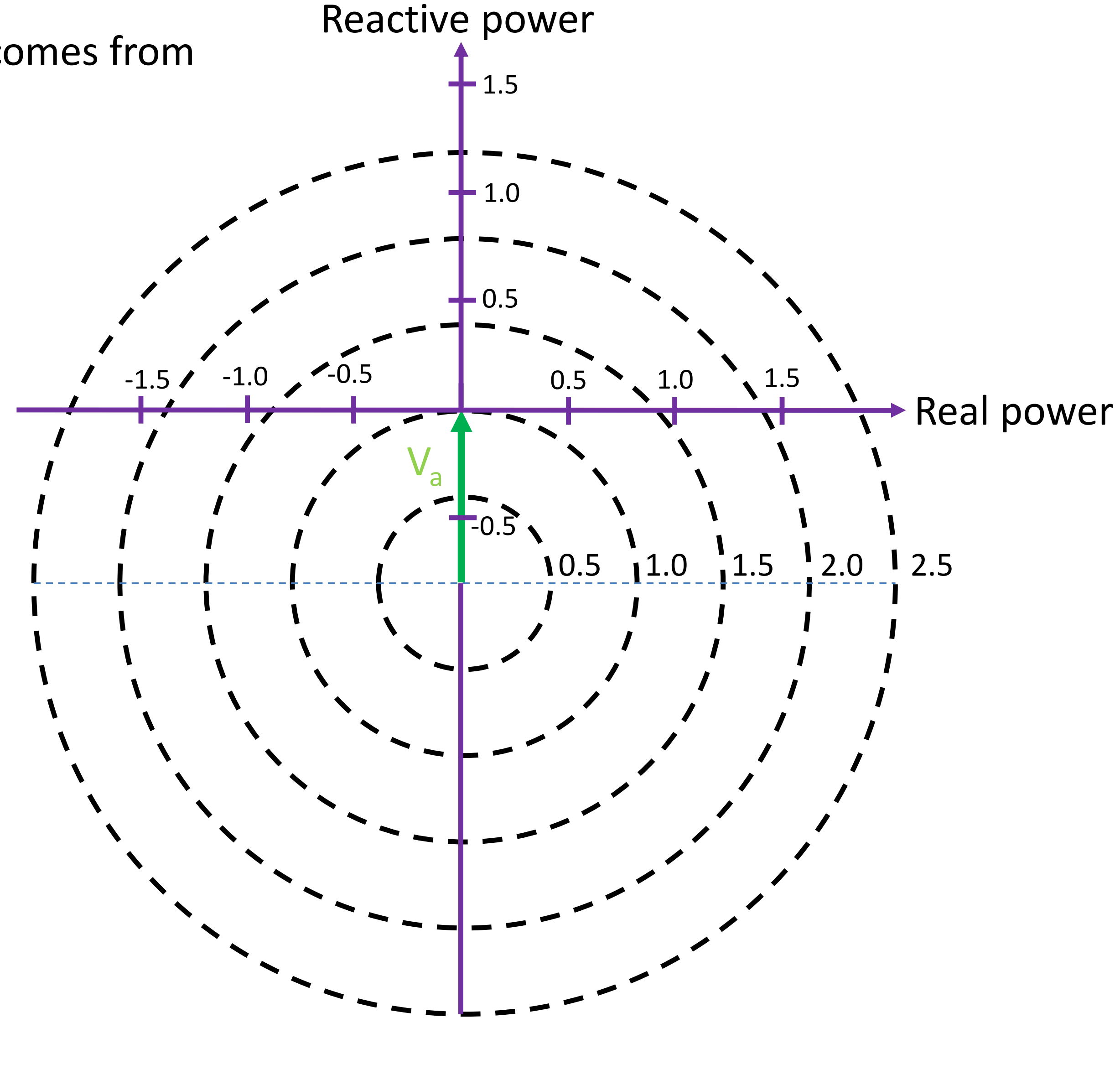


Add on real and reactive power axis (recalling that generating power is negative by convention)

Need to scale to allow for Xs

In this case, scaling of 1.25 comes from

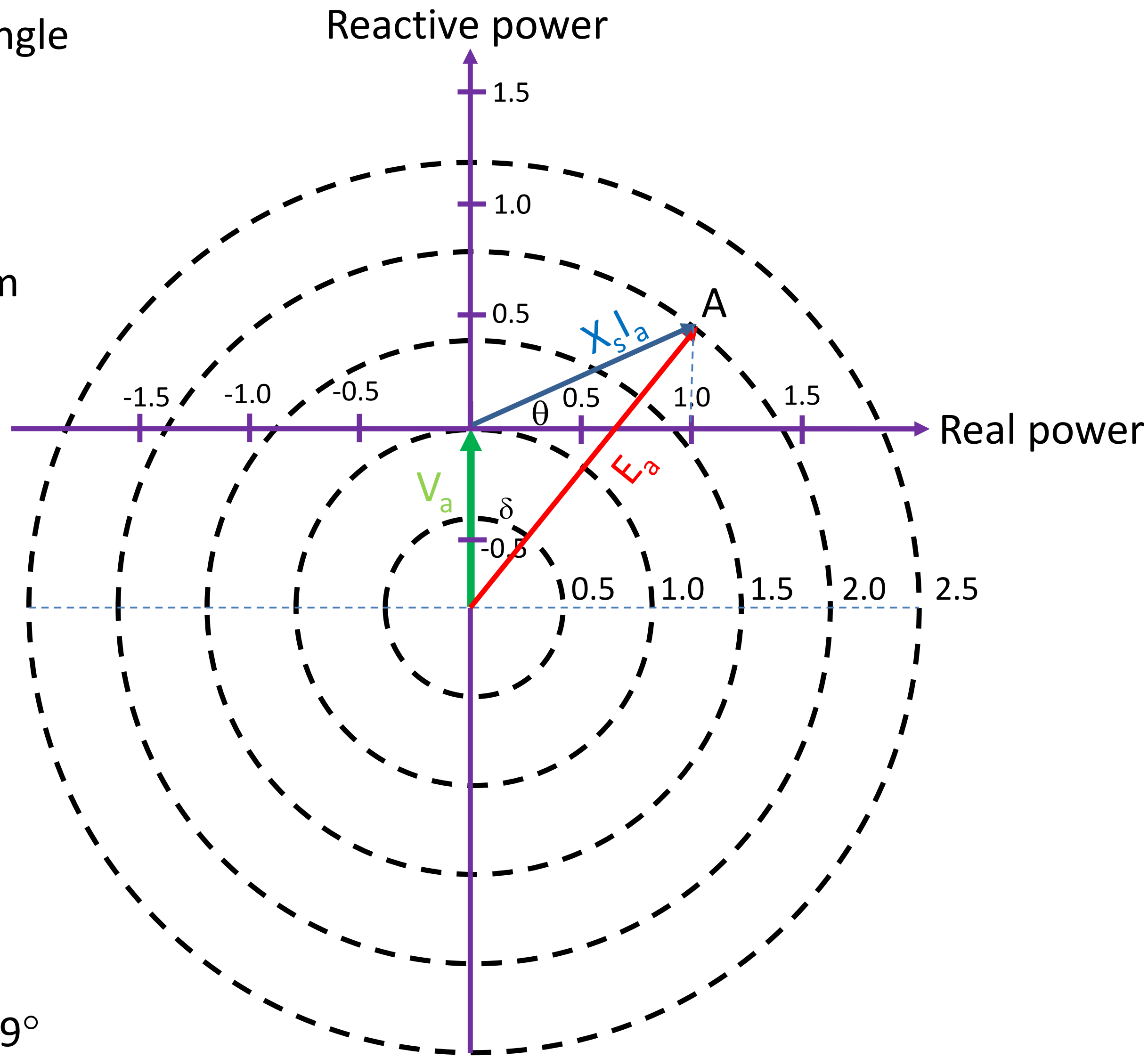
$$P = -\frac{V_a E_a}{1.25} sin\delta$$



Draw on X_sI_a at power factor angle

Draw on E from origin to end point of X_sI_a

Establish E_a and δ from diagram



For point A: measured δ = -39°

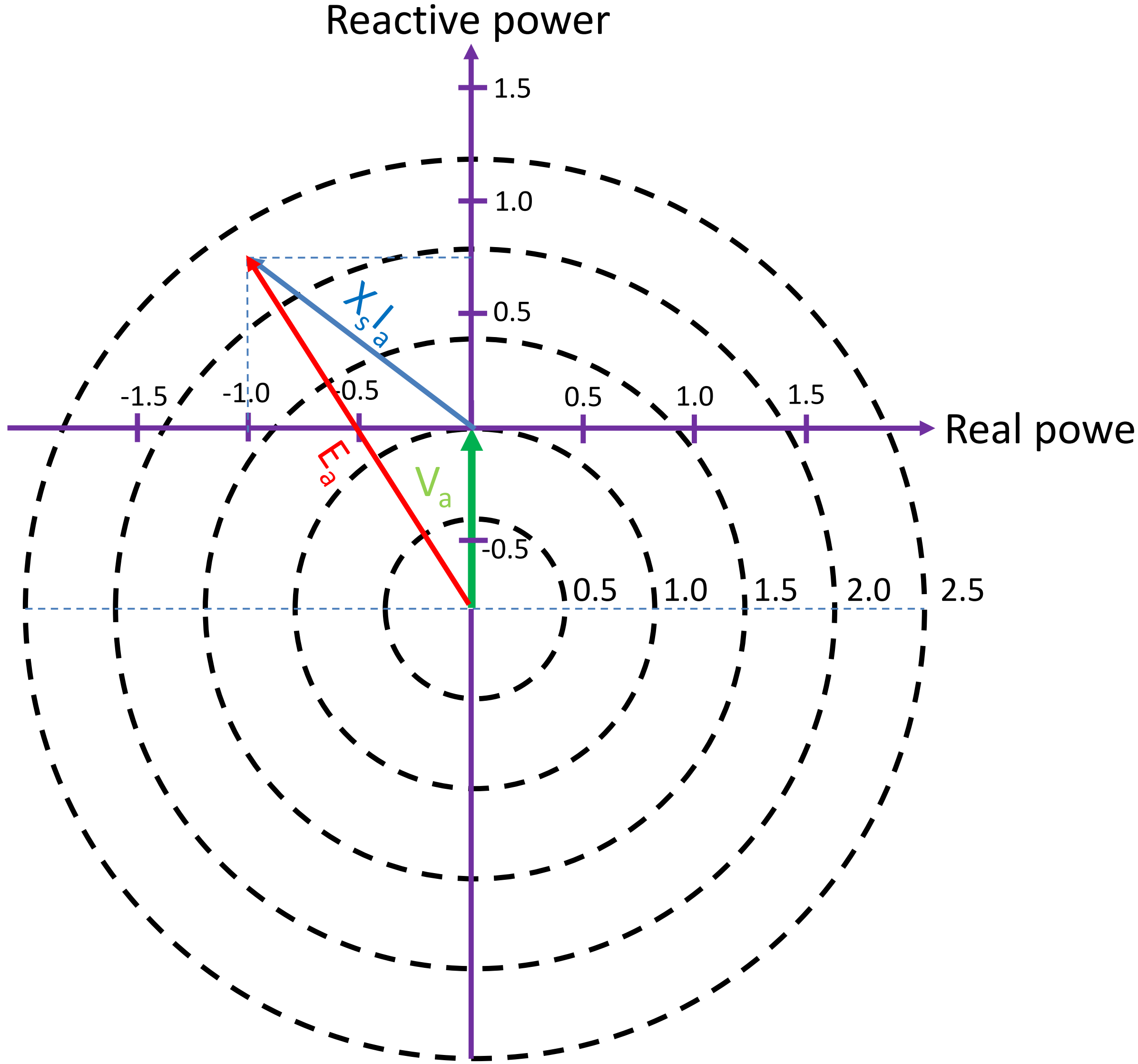
$$P = -\frac{V_a E_a \sin\delta}{X_s} = -\frac{1 \times 2 \times (-0.63)}{1.25} \approx 1.0\, per\ unit\ (as\ per\ load\ diagram)$$

Example – Calculating excitation and load angle from real and reactive power

Calculate excitation and load angle for a machine acting as a generator with P=-1.0 per unit and Q = +0.75per unit

In this case, drawing the phasors yields δ = 33° and Ea = 2.30 per unit

$$P = -\frac{V_a E_a \sin\delta}{X_s}$$
$$= -\frac{1 \times 2.30 \times (0.54)}{1.25}$$
$$\approx -1.0\ per\ unit$$



Steady-state stability limit example

Supposing the mechanical input of 1 per unit is maintained, but the excitation is gradually reduced.

The operating point follows the path shown until the point S is reached at which point δ=90° and hence the limit of stability is reached.

This occurs with an excitation of ~1.25 per unit